CONSULTANT REPORT

# LIGHTING EFFICIENCY TECHNOLOGY REPORT

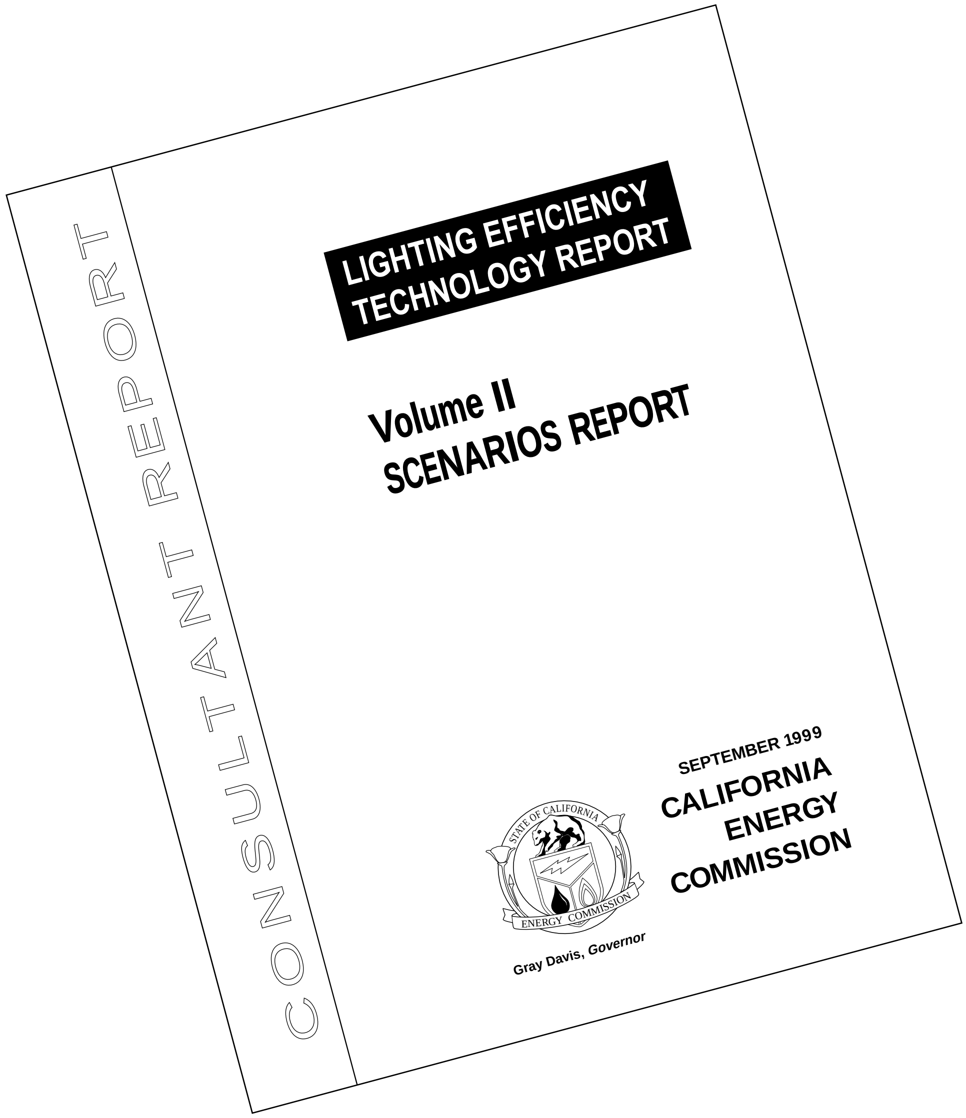
# Volume II
# SCENARIOS REPORT

SEPTEMBER 1999

**CALIFORNIA ENERGY COMMISSION**

Gray Davis, *Governor*

P400-98-004VII




**C A L I F O R N I A   E N E R G Y   C O M M I S S I O N**

*Prepared for:*

**California Energy Commission**

*Prepared by:*

**Heschong Mahone Group**
Fair Oaks, California
Contract No. 400-95-012

Maziar Shirakh, *Program Manager*
Michael S. Sloss, *Manager*

**NONRESIDENTIAL BUILDINGS OFFICE**

Scott Matthews, *Deputy Director*

**ENERGY EFFICIENCY DIVISION**

## ACKNOWLEDGMENTS

This report is one of several being prepared under the *Lighting Technology Assessment Study* for the California Energy Commission. The study is being done as part of the Commission's response to the 1993 California Senate Bill SB 639 in which the legislature requested recommendations on ways to improve the efficiency of lighting in California.

The Commission's project manager for this study was initally Fred Berryman, and then John Sugar, with support from David Jones, and Ross Deter. The contractor team was led by the Heschong Mahone Group, Lisa Heschong and Douglas Mahone, Partners. Data analysis was provided by Ken Parris of B.E.A.R. The California Lighting Model was developed and run by Eley Associates, Charles Eley, Principal and Jeffery Luan, programmer. Additional lighting expertise was provided by James Benya and Ken Lim, and market research by Lisa Heschong of Heschong Mahone Group, Doug Oppedal of Benya Lighting Design and Merry Stubbins of SDV/ACCI.

This report has greatly benefited from additional resources provided by many people and organizations. Key in obtaining access to important databases have been Marian Brown of Southern California Edison, and David Lerman of Tacoma Public Utilities. Additional data was provided by members of Los Angeles Department of Water and Power, San Diego Gas and Electric, The City of Sacramento, CalTrans, and Lawrence Berkeley National Laboratory. Barbara Aktinson, Judy Jennings, and Frances Rubenstien of Lawrence Berkeley National Laboratory were particularly helpful in obtaining background information.

Members of the Lighting Efficiency Advisory Group (LEAGue) have provided information and support. Many retailers, manufacturers and professionals provided important background information for the market barriers study and participated in interviews. They were assured that their responses would remain anonymous. We greatly appreciate all their time and thoughtfulness in contributing to this project. The analysis and recommendations in this report, and any errors, however, are solely the responsibility of the authors.

There are four volumes to this Lighting Efficiency Technology Report:

Volume I: California Baseline Report

Volume II: Scenarios Report

Volume III: Market Barriers Report

Volume IV: Recommendations Report

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# 1. EXECUTIVE SUMMARY

Twenty-five scenarios, and five additional combinations, were studied for potential energy savings using the California Lighting Model developed for this study. These scenarios are described in this report, and the results presented.

## Residential Scenarios

It is clear that interventions which effect the entire residential market, such as marketing campaigns or appliance standards, will have a vastly greater impact than approaches that only effect residential new construction, such as Title 24 energy standards requirements. While the new construction residential scenarios have the ability to save from approximately 0.5% to 1.5% of current residential lighting energy use, the "all building" residential scenarios have the potential to effect from 7% to 21% of current residential lighting energy use, or about a 14 times larger impact.

Residential lighting in general is operated for very few hours per day. In order to achieve significant and cost effective savings, residential lighting efficiency programs should either target those lighting fixtures which operate for the longest hours, or where there are the greatest number of inefficient fixtures.

Outdoor lighting meets both of these criteria. Outdoor lighting efficiency measures show the greatest savings for the residential new construction approaches considered in this study, and almost ten times those savings when applied to all homes.

Targeting residential lighting fixtures which operate for three or more hours per day for replacement with more efficient light sources shows even greater potential savings. Placing tungsten halogen infrared lamps in these fixtures can save about 12% of current residential lighting energy use, while using compact fluorescent lamps in these fixtures has the potential to save 21%.

Targeting table lamps and floor lamps for replacement with more efficient sources also has considerable impact, since there is such a huge number of these fixtures. Automatic controls which can eliminate unnecessary hours of operation also have potential to save considerable residential energy. It is also clear that current trends in increased energy use for lighting in residences, such as the increased use of powerful halogen torchiers, could significantly reduce any gains from an aggressive lighting efficiency program, and could completely cancel any gains from a modest program.

Potential energy savings from the "'all building" residential scenarios are on a par with those considered for commercial buildings. This similarity in energy savings potential exists in spite of the fact that commercial lighting hours of operation are 4 times longer than residential. The similarity in savings exists primarily because the residential sector is so large, with 3 times as much installed wattage as the commercial sector, and because residential lighting currently uses much less efficient sources than commercial, and so there is much greater potential for savings from efficiency improvements.

## Commercial Scenarios

The analysis shows that there is significant potential for energy savings and demand reduction in commercial lighting, without reducing current lighting levels. Modest savings could be achieved by lowering Title 24 requirements by a uniform 10%, resulting in an average reduction of 0.06 watts/sf for commercial space overall. However, reductions on the order of 0.45 watts/sf for the whole building stock overall, or 7½ times greater than a uniform 10% Title 24 reduction, are obtainable with existing technologies and design methods.

Converting fluorescent technologies to the equivalent of T8 lamps and electronic ballasts, a change that is already well underway in the marketplace, saves more energy and reduces wattage more than lowering Title 24 by a uniform 20%. This single change also has substantially greater impact than adopting the national ASHRAE/IESNA 901.R standards currently proposed for commercial building lighting.

The savings reaped from a conversion to T8 lamps and electronic ballasts can be doubled if all commercial lighting is converted to the most efficient alternative which is commercially available in 1996. An additional 68% in energy savings, and 28% reduction in wattage could be further achieved through other viable lighting efficiency methods such as careful lighting design, use of automatic controls and daylighting.

## Combined Residential and Commercial Scenarios

General promotion of efficient incandescent A-lamp replacements are likely to effect both the residential and commercial sectors. We looked at the combined residential and commercial impacts of either a compact fluorescent lamp (CFL) or a halogen infrared lamp (HIR) replacement, and found them to be dramatic. The large number of target fixtures in the residential market and the large amount of energy and demand savings possible in the commercial market make these combined strategies have an impact on par with the most aggressive commercial scenarios. An HIR A-lamp replacement results in about 1,000 megawatts of demand reduction in California, while a CFL replacement results in about 1,500 megawatts of demand reduction. The resulting energy savings are 4,340 gigawatthours and 7,468 gigawatthours per year respectively.

## Demand Impacts

Installed watts reduction for commercial scenarios are also on a par with installed watts reduction for the residential scenarios, ranging from 40 megawatts to 1,872 megawatts for commercial, and from 42 megawatts to 8,783 megawatts for residential. Reductions in installed lighting watts for commercial buildings are generally more effective in reducing demand impacts on utilities than equivalent reductions in the residential sector.

Commercial lighting loads tend to very closely mirror occupancy, or hours of operation for a given building type. Since most commercial buildings are occupied during periods of peak demand (generally summer afternoons and evenings), reducing installed lighting wattage for commercial buildings directly reduces peak building electrical demand in most cases.

Residential lighting profiles, in contrast, tend to peak at 7 to 8 PM in the summer, often after the utility system peak demand. This means that residential lighting demand reductions are generally less valuable to utilities in their load management programs. Residential lighting efficiency programs that reduce the energy use of floor and table lamps will have the greatest impact on residential peak loads.

# 2. MODELING METHODOLOGY

The California Lighting Model (CLM) was developed to estimate statewide lighting savings for various lighting efficiency scenarios. The CLM uses baseline lighting characteristics derived from a substantial set of surveys of actual buildings in California performed between 1992 and 1994. This survey data includes very detailed inventory of lighting technologies by space type and building type, and the hours of operation of those lighting systems. The survey data was matched to the overall residential and commercial building populations projected for the next 15 years by the CEC.

The CLM is used to assess the statewide energy impacts of lighting efficiency “scenarios”, which model the effects of various policy options or market strategies. A scenario in the model includes a set of assumptions for how the market penetration of various lighting technologies (lamps, ballasts, controls) will change over time, or how the lighting power density of a space type will be changed. Energy impacts are assessed over the 15 year study period.

A description of the structure of the relational database for the CLM and the baseline inputs for both the residential and commercial model are included in the Appendices to this Volume.  Also included in the Appendices are the specifications for the various scenarios which were studied.

## 2.1 Lumen Shares

Most of the scenarios involve substituting one type of lamp and/or ballast for another.  The net effect of these substitutions is to improve the efficacy of the lighting source, and thereby to reduce the installed lighting power and energy consumption.  The model uses a lumen target for each space or application type, which is the total number of lumens generated by lamps in the surveyed buildings, based on typical lamp/ballast efficacies.  The model then maintains a constant lumen output as we substitute lamps, ballasts or fixtures.  The wattage changes, then, result primarily from improvements in efficacy, rather than from changes in light levels.

There is an exception to this for some scenarios (particularly commercial scenarios), where we adjust the total lumen levels downward.  For example, in a scenario that presumes that lighting designers start using more efficient luminaires and design strategies, we assume a reduction in the mean lumen output required from the lamps, while the delivered lumens to the task would remain the same.

Ultimately, the model converts lumens into installed wattage, which allows us to then apply operating hours and control strategies to arrive at lighting energy use. But by holding lumens constant, we are keeping the comparisons between base case and scenarios comparable to each other.

We assume that illuminance levels are a consumer preference that should be taken as a given. This assumption is supported by our analysis of both the residential and commercial datasets by the vintage of the building, in which we were not able to detect any trends in lumen level changes over time. We don't actually know what the illuminance levels are in any of the surveyed space. They could be below, or above, IES recommended levels. We have no information on room conditions which would allow illuminance levels to be calculated. We do, however, know that a very large sample of California commercial buildings are operating at these lighting levels, which must, therefore, have a reasonable level of market acceptance. The confidence levels for the mean lumen output by building type, which are presented in Volume I, were actually found to be fairly precise, suggesting a relatively small variation in room conditions and lighting level preferences among the general population for each building type.

Because the model specifies an efficacy for a given lamp-ballast combination, we are not explicitly modeling a lighting product, but rather a given efficacy level. Thus, although the scenarios may describe "compact fluorescents", or some other lamp-ballast combination, a more accurate interpretation would be "a lamp/ballast technology of equivalent efficacy to a compact fluorescent with electronic ballasts."

## 2.2 New Construction vs. "All Buildings"

One of the most important distinctions in the scenarios is between new construction and "all buildings". For both classes of construction, we have obtained projections of numbers of units for each year between 1995 and 2010. The residential projections are in terms of households, broken out between single family (SF) and multi-family (MF). The commercial projections are in terms of square footage, broken out by ten building types.

In our modeling of "new" and "all building" scenarios, we generally assume high levels of penetration for the new buildings. This is because most of these scenarios assume a requirement that applies to all new construction. On the other hand, we generally assume much lower levels of penetration for "all buildings" scenarios, because the turnover rates of lighting in existing buildings is much more gradual, and less subject to enforcement.

The “new buildings” numbers are used to project savings that would apply only to new buildings built after a given efficiency improvement is implemented. For example, if a change was made in Title 24 that required a particular efficiency measure, the savings would accrue primarily in new buildings governed by Title 24. The construction projection numbers list the numbers of new buildings assumed to be built for each year. These savings are cumulative over the 15 years of data that we have in our model, with a given year’s savings repeating for each of the following years until the year 2010. The total savings for the 15 year period is then the sum of the accumulating annual savings.

Residential new construction only includes new homes projected for each year. Commercial new construction, on the other hand, includes the assumption that 5% of the existing commercial building stock has its lighting system renovated in a given year. This assumes an average 20 year life for a lighting system before it undergoes renovation. Since 10% vacancy rates are fairly common for commercial real estate, this 5% assumption seems realistic. At a 5% renovation rate, and with a slight attrition in existing stock per year, only 10% of the 1995 existing commercial building stock remains with its original lighting system in 2010. This is shown below in Figure 2-1. Changes in this renovation rate would have substantial impact on the energy savings from the commercial scenarios.

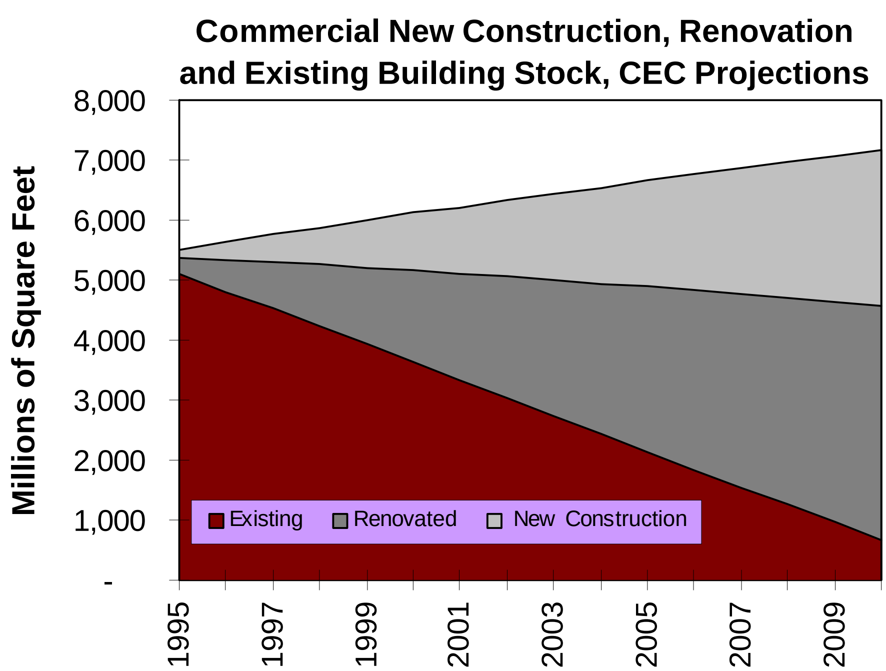



*Figure 2-1 - Commercial New Construction, Renovation and Existing Building Stock*

The “all building” numbers are used to project savings that would develop through retrofits or incremental changes to existing buildings, along with equivalent improvements in new construction. For example, if an appliance efficiency standard were to require that only electronic ballasts be sold, then any ballast change-outs or retrofits would experience the energy savings, plus new buildings would have only electronic ballasts.

At the end of the 15 year study period, the difference between the total commercial square footage ultimately effected by a new construction vs. an “all buildings” scenario is very small. In residential scenarios, however, the difference between projected savings for new construction vs. “all building” scenarios is dramatic. This is because residential renovation, which is rarely subject to Title 24 requirements, is not included in the new construction calculations. By 2010 at the end of the 15 year study period, homes constructed since 1995 represent only 19% of all homes. New construction scenarios effect only this smaller population. “All building” scenarios, on the other hand, include the entire residential population, and thus have a much larger impact. Figure 2-2 show these population projections. If substantial residential renovation is achieved through the new construction process, the savings for residential new construction scenarios would increase.

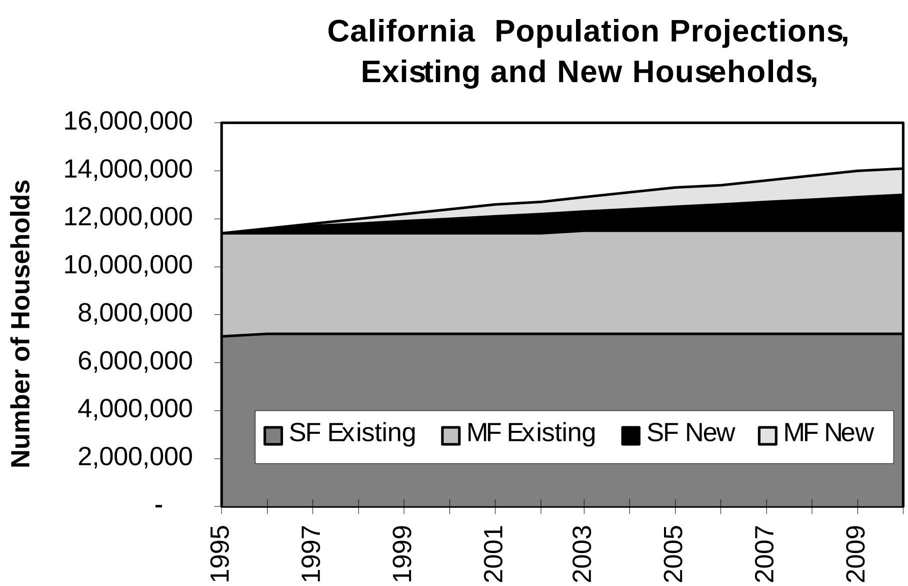



*Figure 2-2 - Projection of California Household Population*

(Residential attrition is not accounted for because these figures are for the number of households, not the number of dwelling units. The final calculation, however, does account for a 0.5% increase in energy use each year for new construction, due primarily to the increased size of houses built over time.)

## 2.3 Penetration Curves

Because our model projects savings for efficiency improvements over the next fifteen years, we are able to vary the rate of penetration for various options. Penetration is our measure of the percentage of buildings which have implemented a given efficiency option. This allows us to distinguish between an efficiency option that would achieve high penetration very quickly, such as an appliance standard that outlaws a particular technology and so prevents its use in all new buildings, versus an option that would achieve slow penetration, such as a long-term effort to educate consumers to use more effective time controls for their outdoor lighting.

We have developed four penetration curves for use in our modeling. For all of these curves, we specify the difference between the base case condition (1995) and the final condition(year 2010). The model then uses one of the curves to fill in the intervening years. The four curves are:

**Straight Line Penetration -** This assumes a constant rate of increase in the penetration of an efficiency option over time.

**Early Penetration -** This assumes that penetration climbs quickly during the first five years, and then begins to level off at a high level for the final ten years.

**Late Penetration -** This assumes that penetration climbs slowly during the first ten years, and accelerates during the final five years.

**Classic Penetration -** This assumes slow penetration during the first five years, followed by five years of rapid increase in penetration, leveling off at a high level for the final five years. This is a classic “S-shaped” penetration curve for a new product. After 15 years, this penetration curve has almost the same net results as straight line penetration.

The choice of penetration curve depends on the type of construction and the type of implementation approach assumed for each scenario.

### *2.3.1 Reporting of Results*

The effect of each scenario is computed over the 15 year study period, from 1995 to 2010. Energy savings from each scenario are reported in three primary formats.

1. **Installed Watts Reduction** - This value measures the reduction in statewide connected load for the overall building population in the 15$^{th}$ year. The units reported are reductions in megawatts, or one million watts. Residential lighting installed lighting load is currently about 22,800 megawatts.

Commercial indoor installed lighting load is currently about 7,500 megawatts.

While “installed watts reduction” might loosely be referred to as a “demand reduction,” in reality, it is only a very rough proxy for demand reduction. Demand reduction depends upon the proportion of the connected load which is in operation during a peak demand period. If 80% of lighting watts in all buildings are on during a peak demand period, then the actual reduction in demand due to a scenario might be only 80+/-% of the “installed watts reduction” reported here. Load shapes for residential lighting are shown in Volume I - California Baseline Report, Section 3. Commercial lighting load shapes are shown in Section 4 of Volume I. When estimating demand reductions we have used 3PM and 6PM in the summer as peak periods.

Demand reduction is more complex than “installed watts reduction” in other ways. For any given scenario it will depend on which types of lights are specifically on for that period. We also do not report any installed wattage reduction for automatic controls, because the total connected load is not reduced. Automatic controls can, however, reliably reduce demand if they are responsible for turning lights off during peak demand periods.

2. **Energy Savings per Year in 15$^{th}$ Year** - This value reports the reduction in lighting energy use per year of the scenario, compared to baseline conditions, in the 15$^{th}$ year. For the baseline condition, the population increases, but lighting energy use remains static over the 15 years. For the scenario, the population increases, and energy use changes per the scenario. We use the last year of the study because maximum penetration rates are assumed to have been reached for each scenario.

   The units reported are savings in gigawatt hours per year. A gigawatt hour is equivalent to one billion watt-hours, or one million kilowatt hours. Current residential energy use is about 19,500 gigawatthours per year. Commercial indoor use is currently about 27,300 gigawatthours per year.

3. **Cumulative Energy Savings over 15 Years** - The energy savings for each year over the 15 year study period are added up to produce the cumulative savings. Each year, there are greater savings as the technology in question achieves greater penetration. There are also more buildings which are effected, as the overall population increases.

   The cumulative savings are effected by which penetration scenario is selected. Early penetration results in faster accumulation of savings, while late penetration diminishes the cumulative savings. The sensitivity of the results to the choice of penetration curve is discussed below.

The units reported are savings in gigawatthours. These cumulative values are generally 5 to 10 times larger than the yearly savings reported for the 15th year.

### 2.3.2 Parametric Runs on Penetration Curves

Parametric runs were done to study the relative impact of choosing different penetration levels or penetration rates for the scenarios. Changing the penetration levels had a direct relationship to energy savings. Thus, if the penetration level was reduced by ½, the resulting energy savings were also reduced by approximately ½.

The choice of different penetration rates had a more complex impact, and varied between new construction and all building scenarios. The graph below in Figure 2-3 illustrates the relative impact of different penetration rates on residential new construction scenarios, and compares them to a straight line penetration rate as the standard.

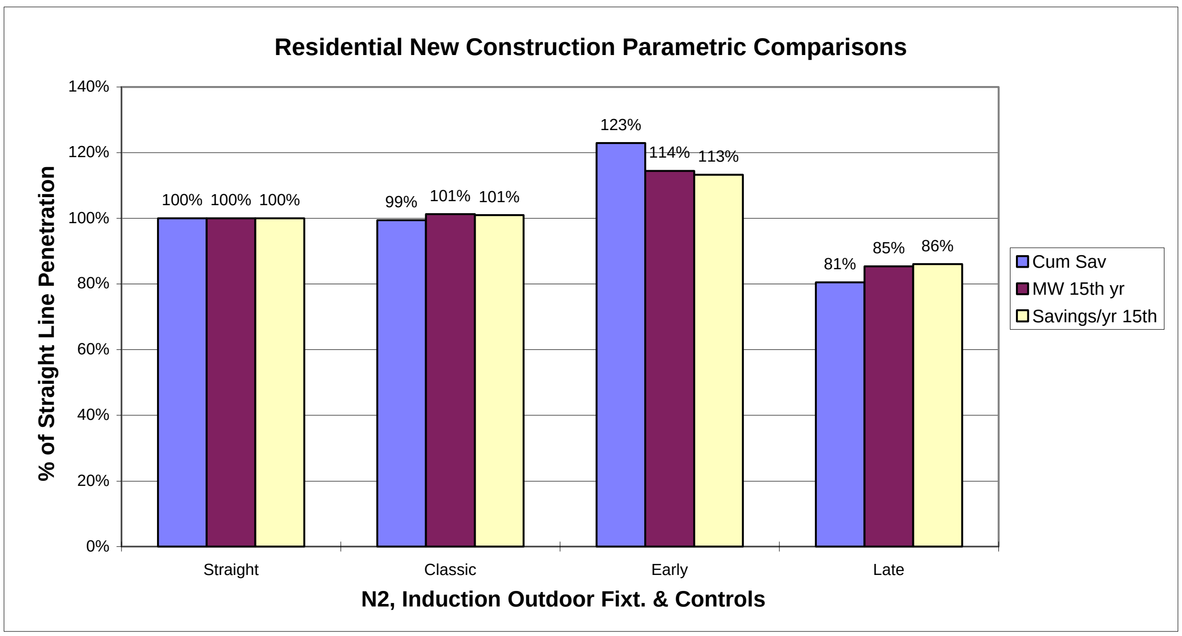



*Figure 2-3 - Residential New Construction, Parametric Comparisons*

A classic "s-shaped" penetration has essentially the same impact as a straight penetration except for savings in the 15th year, which increase by about 17%. Early penetration increases the demand reduction in the 15th year by 14% and the energy use in the 15th year by 32%. Cumulative energy savings over those 15 years are larger by 23%. Late penetration decreases the demand reduction by 15% but increases the savings in the 15th year 16%. Cumulative savings are smaller by 19%. This pattern remains essentially the same for all residential new construction options.

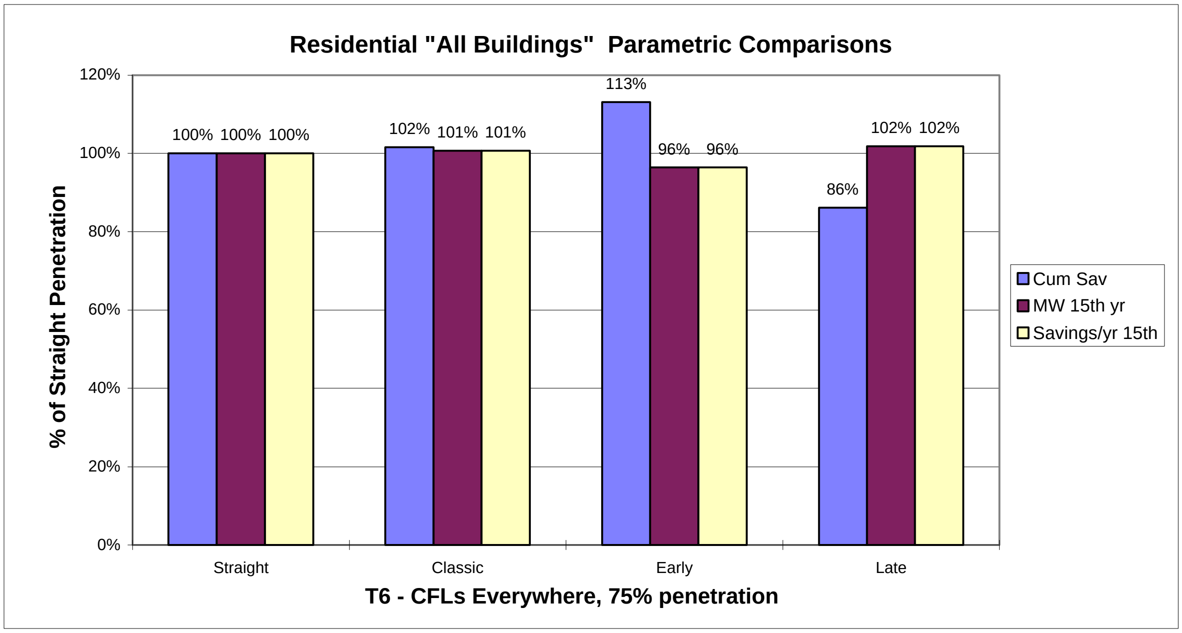



*Figure 2-4 - Residential "All Buildings" Parametric Comparisons*

The "all buildings" scenarios for the residential sector show a much less exaggerated pattern for the impact of the various penetration rates, plotted above in Figure 2-4 for scenario T6. There is little change for any result, except for a 13-14% difference in cumulative energy savings for early or late penetration rates.

The curves for the various penetration rates can be adjusted in the model. However, for simplicity's sake, we stayed with the four curves described here.

# 3. RESIDENTIAL LIGHTING

Please refer to the California Baseline Report, Volume I in this study, for information on residential baseline lighting characteristics.

## 3.1 Residential Scenarios

The following paragraphs provide a brief description of each of the residential scenarios we have analyzed, followed by results and comments. They are presented first for scenarios effecting only the new construction which occurs during the 15 year study period. The second group are those scenarios which effect all of the existing housing stock plus new construction during the 15 year study period. The energy impact of the residential scenarios are summarized in the graphs in Figure 3-3 at the end of this section.

The designator code at the beginning of each scenario title is used as a short hand reference; it is included here for consistency and convenience. The assumptions for each scenario are described briefly here. The full detail for the assumptions for each scenario are included in the Scenario Specifications in the Appendix to this report.

### *3.1.1 New Construction Residential Scenarios*

The following scenarios apply to residential new construction only. They assume policies or strategies that effect only the new homes built each year. Energy impacts are calculated for the cumulative effects of 15 years of new home construction.

#### N1 Outdoor Lighting Efficacy

This scenario assumes that wall and ceiling mounted outdoor fixtures gradually change from incandescent to compact fluorescent sources. The scenario assumes that the lumen share of incandescent lamps in these fixtures is reduced by 50%, and that the lumens provided by compact fluorescent lamps increase by the same amount. A straight line penetration is assumed. The incandescent lamps are 150W or smaller; larger incandescent lamps are not found in significant quantities. Outdoor HID lamps are not changed.

This is a modest improvement in outdoor lighting for new homes. It could probably be achieved through market initiatives to make hard-wired compact fluorescent outdoor fixtures more common, rather than through regulation.

This scenario was found to reduce installed watts by 128 megawatts and save 152 gigawatthours per year in the year 2010. This is equivalent to reducing the statewide lighting load by 64,000 homes, or reducing the lighting energy use by 89,000 homes. This savings represents 0.7% of current residential lighting energy use. Over 15 years it is projected to save approximately 831 gigawatthours of energy.

The performance of fluorescent lamps can be sensitive to air temperature. In cold temperatures, some lamps put out less light than their base rating. Also, in cold temperatures, some fluorescent ballasts have a more difficult time starting the lamp. These problems can be ameliorated somewhat with improved technologies—such as amalgam lamps that maintain their light output at lower air temperatures, and electronic ballasts that are less sensitive to cold weather starting.

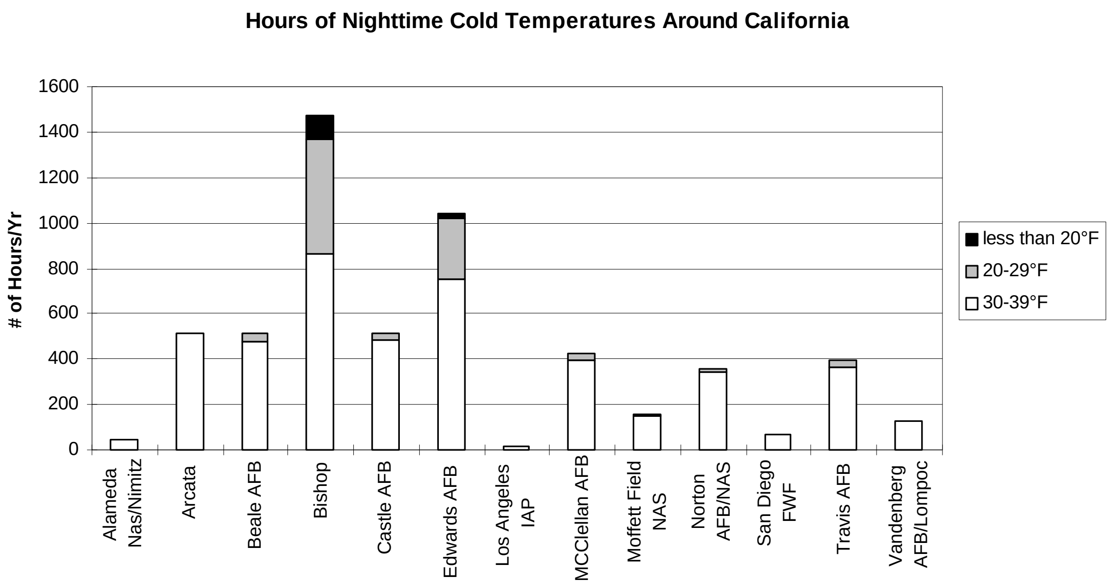



*Figure 3-1 - Hours of Nighttime Cold Temperatures around California*

Figure 3-1shows the frequency of nighttime cold weather at 13 California locations. Mountain or high desert areas, such as at Bishop or Edwards Air Force Base, show 25 to100 hours per year with temperatures less than 20°F and 250 to 500 hours per year with temperature between 20°F and 29°F. For most of the rest of the state, temperatures are rarely below 30°F, and for the major population areas along the coast, such as San Diego, Los Angeles and the San Francisco Bay Area, temperatures rarely go below 40°F.

This analysis of air temperatures implies that standard CFL technologies could provide adequate nighttime outdoor performance for most of California's coastal population centers. Amalgam lamps and/or electronic ballasts might provide better performance in the inland areas, such as the Sacramento and San Joaquin Valleys (such as at Beale, Castle, McClellan, and Travis AFBs, above), which see more hours of cold weather at night.

## N2 Outdoor Induction Lamps and Controls

This is a more aggressive version of the previous scenario. In this scenario, all wall, ceiling and lantern mounted outdoor fixtures change from incandescent to electrodeless fluorescent (induction) lamps, which have advantages for outdoor applications over compact fluorescents. They are not sensitive to air temperature, and are not impacted by frequent switching which could be caused by motion detector controls. These electrodeless lamps are assumed to have an efficacy of 50 lumens/W. Late penetration is assumed, allowing time for the technology to develop further. In addition, this scenario assumes that all outdoor fixtures with on/off switches are converted to motion detector/photocell controls, which reduce the average hours of operation by 25%. Outdoor HID lamps are not changed.

This scenario probably sets an upper limit on the savings potential for outdoor lighting in new construction. It presumes rapid advancement in this technology, with a corresponding drop in cost, and a regulatory change that requires the new equipment in all new homes.

This scenario was found to reduce installed watts by 243 megawatts and save 341 gigawatthours per year in the year 2010. This is equivalent to reducing the statewide lighting load by 122,000 homes, or reducing the lighting energy use by 200,000 homes. Over 15 years it is projected to save approximately 1,785 gigawatthours of energy, the largest of all the residential new construction scenarios. For comparison, this is about the same order of magnitude as the smallest of the residential retrofit scenarios (T2), and about 6 times larger than the impact of perfect kitchen fixture compliance (N4) with Title 24.

## N3 CFL Ceiling Fixtures

This scenario assumes that all indoor ceiling mounted fixtures throughout the house are installed with fluorescent lamps, except for fixtures with large incandescents (150+W), which are converted to halogen lamps, and chandeliers, which are not affected. An early penetration is assumed.

This scenario calculates the maximum potential savings that could be achieved from requiring hard-wired fluorescent fixtures inside new homes.

This scenario was found to reduce installed watts by 336 megawatts and save 254 gigawatthours per year in the year 2010. This is equivalent to reducing the statewide lighting load by 168,000 homes, or reducing the lighting energy use by

149,000 homes, or 1.3% of current residential lighting energy use. Over 15 years it is projected to save approximately 1,510 gigawatthours of energy, the second largest of all the residential new construction scenarios.

## N4 Fluorescent Kitchen Fixtures

This scenario calculates the savings potential of expansion and increased enforcement of the Title 24 requirement for fluorescent fixtures in kitchens. It assumes that all incandescent lighting in ceiling surface, suspended, and recessed, and under cabinet fixtures in kitchens is converted to compact fluorescents. An early penetration rate is assumed.

This scenario sets an upper bound on the savings potential for improved compliance/enforcement of the existing Title 24 requirement for kitchen lighting. It attempts to model the statewide savings from 100% fluorescent lighting in kitchens. In reality, Title 24 does not require 100%, or even 50%, fluorescent lighting in kitchens. Thus, perfect compliance with the current code requirements for kitchen lighting would likely result in only about ½ of savings projected for this scenario.

This scenario was found to reduce installed watts by 42 megawatts and save 50 gigawatthours per year in the year 2010. This is equivalent to reducing the statewide lighting load by 21,000 homes, or reducing the lighting energy use by 29,000 homes. Over 15 years it is projected to save approximately 297 gigawatthours of energy, the smallest of all the residential new construction scenarios modeled.

## N5 Fluorescent Bathroom Vanity Fixtures

This scenario assumes that all bathroom vanity fixtures shift from incandescent to fluorescent sources, with a late penetration curve.

This scenario could possibly be achieved through market initiatives that make attractive fluorescent fixtures the norm in about ten years. However, given current resistance in the market, it most likely would require regulation to guarantee a market for manufacturers to respond to.

This scenario was found to reduce installed watts by 182 megawatts and save 150 gigawatthours per year in the year 2010. This is equivalent to reducing the statewide lighting load by 91,000 homes, or reducing the lighting energy use by 88,000 homes. Over 15 years it is projected to save approximately 890 gigawatthours of energy, in the mid-range of the residential new construction scenarios.

Bathroom vanities do not have especially long hours of operation (1.93 hours per day on average), however there are a lot of them and they have high watts/fixture (125 W/fixture). They are the fourth most common application type defined in this study, after bedroom and living room table lamps, and outdoor wall mounted fixtures, and the seventh highest in watts per fixture. These factors combine to make them the second highest application type in terms of total installed wattage, after wall mounted outdoor fixtures.

### N6 Fluorescent Garage and Utility Fixtures

This scenario assumes that all garage and utility room fixtures are either required to be of fluorescent efficacy or greater, or to have an automatic control. Given that a large percentage of garage fixtures are already fluorescent (about 46% of garage lighting energy use and 11% of utility rooms' is currently fluorescent) and that controls can often be inappropriate for these locations, the scenario was modeled with 75% of fixtures in these locations being switched to fluorescent sources and 25% of the fixtures on controls which reduce the average hours of operation by 15%. It was modeled with a straight line penetration curve.

This scenario was found to reduce installed watts by 86 megawatts and save 84 gigawatthours per year in the year 2010. This is equivalent to reducing the statewide lighting load by 43,000 homes, or reducing the lighting energy use by 49,000 homes. Over 15 years it is projected to save approximately 459 gigawatthours of energy, the second smallest of all the residential new construction scenarios.

There are probably the fewest market barriers to this residential scenario because fluorescent lighting is already widely used in these locations. Such a regulation, however, would undoubtedly strengthen the association of fluorescent lighting with “utility” lighting, and reinforce the presence of fluorescent fixtures in the low end of the residential fixture market.

The utility rooms and garages have relatively long average hours of operation. They tend to have very intermittent use, making them a good candidate for automatic controls. However, their sample sizes in our study were also comparatively small, and thus the level of certainty for their hours of operation is lower than for other room types.

## *3.1.2 All Building Scenarios*

The following scenarios apply to all residential buildings, both existing and new construction. They assume policies or strategies that effect the entire residential housing market through market based, consumer oriented initiatives or appliance regulation.

## T1 Outdoor Lighting Efficacy and Controls

This scenario assumes that 50% of the incandescent lumens in outdoor wall and ceiling fixtures are converted to compact fluorescents. It also assumes that fixtures with on/off switches and long hours of operation are converted to motion detectors. A straight line penetration is assumed.

This scenario is based on the EPA Energy Star Outdoor Lighting proposal. It is a more modest version of the N2 scenario for new construction described above, however, it has far greater impact than N2 because it would effect all homes, not just new homes. The lamp and control conversion make sense with current technology. They can either be sold with new fixtures or retrofitted to existing fixtures.

This scenario could be achieved through an appliance regulatory approach that required Energy Star specifications for all outdoor fixtures sold in California. Alternatively, it might be achieved through aggressive marketing approaches instead of regulation. This less aggressive approach would result in corresponding less savings and slower penetration.

This scenario was found to reduce installed watts by 1,439 megawatts and save 1,985 gigawatthours per year in the year 2010. This is equivalent to reducing the statewide lighting load by 721,000 homes, or reducing the lighting energy use by 1,165,000 homes, or 10.2% of current residential lighting energy use. Over 15 years it is projected to save approximately 14,344 gigawatthours of energy. This scenario reduces installed watts by 6 to11 times that of the new construction scenarios dealing with outdoor lighting (N2 & N1 respectively), and increases yearly energy savings by 6 to 13 times.

## T2 CFL Lamps in Torchiers

This scenario assumes that torchiers lamps (defined as floor lamps which have tungsten halogen or incandescent bulbs greater than 150 watts) are replaced with compact fluorescent lamps, a more efficacious source. 80% of the lumens are converted, following a late penetration scenario. This scenario does not assume any change in the penetration rate numbers of torchiers from the current levels.

This scenario presumes some regulatory action that would virtually eliminate large incandescent and halogen sources for torchier fixtures, and replaces them with compact fluorescent sources.

This scenario was found to reduce installed watts by 298 megawatts and save 252 gigawatthours per year in the year 2010. This is equivalent to reducing the statewide lighting load by 149,000 homes, or reducing the lighting energy use by 148,000 homes, or 1.3% of current lighting energy use. Over 15 years it is projected to save approximately 1,514 gigawatthours of energy.

Although this scenario shows the smallest energy savings of all the building residential scenarios, it show the same order of magnitude of savings as the most aggressive of the residential new construction scenarios (N2, induction lamps and controls for outdoor fixtures, and N3, fluorescent light in all ceiling fixtures).

## T3 CFL Lamps in Torchiers, Floor and Table Lamps

This scenario builds on the previous one which replaced compact fluorescent lamps in most torchiers, and further assumes that 80% of the lumens in all table and floor lamps, except for task lamps and small table lamps (which generally have shorter hours of operation), are converted to compact fluorescents from incandescent. It presumes a substantial marketing campaign or regulatory effort to virtually eliminate incandescent and halogen sources for portable residential lighting.

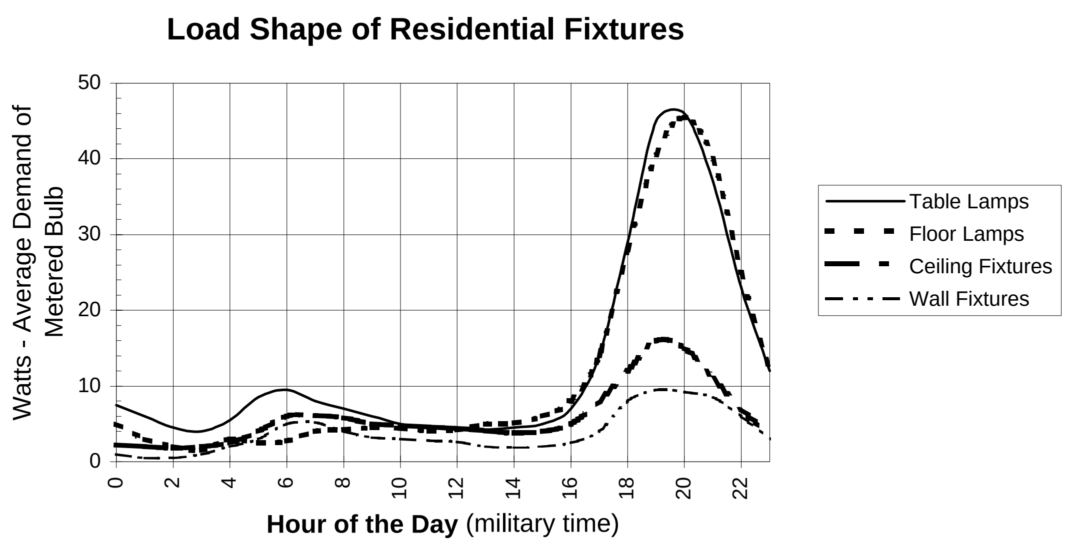



*Figure 3-2 - Load Shapes for Residential Fixtures*

It is significant that this scenario, which is aimed at floor and table lamps, reduces the most significant peak loads for residential lighting, which are generated by table and floor lamps. Table lamps and floor lamps are the major contributors to the residential peak lighting load, which takes place between 6 and 9 PM, as shown in Figure 3-2 above.

This scenario was found to reduce installed watts by 1,963 megawatts and save 1,291 gigawatthours per year in the year 2010. This is equivalent to reducing the statewide lighting load by 984,000 homes, or reducing the lighting energy use by 758,000 homes. Over 15 years it is projected to save approximately 7,772 gigawatthours of energy.

This scenario saves 5 to 6 times the energy of T2, which only looked at converting torchiers to CFL use.

## T4 Time Limiting Controls

This scenario assumes that 80% of all on/off switches on hard-wired fixture types (i.e., all except floor and table lamps) are replaced with time limiting controls which automatically turn off unneeded lights. This is assumed to reduce average hours of operation by 10%. Late penetration is assumed.

The purpose of this scenario is to test the amount of savings that could be obtained from an across-the-board reduction in hours of lighting using controls that have a modest overall impact on average hours of operation. The scenario presumes a slow but large penetration of this kind of technology. The actual hardware could be a combination of control types, including occupancy sensors, timers, or other types of controls that reduce unnecessary lighting hours.

This scenario was found to reduce installed watts by 0 megawatts and save 1,413 gigawatthours per year in the year 2010. There is no reduction in statewide lighting load, however the scenario reduces statewide lighting energy use by the equivalent 829,000 homes. Over 15 years it is projected to save approximately 11,793 gigawatthours of energy.

## T6 CFL lamps in all Applications

This scenario assumes that 75% of all incandescent lumens, in all fixture types, are converted to fluorescent sources, following a late penetration curve.

This scenario sets an upper limit on the savings potential from eliminating most incandescent lighting in homes. It presumes a massive regulatory effort directed at virtually all residential lighting, with a substantial success rate within fifteen years.

This scenario was found to reduce installed watts by 8,783 megawatts and save 7,941 gigawatthours per year in the year 2010. This is equivalent to reducing the statewide lighting load by 4,403,000 homes, or reducing the lighting energy use by 4,660,000 homes, or 40.8% of current residential lighting energy use.

Over 15 years it is projected to save approximately 47,823 gigawatthours of energy.

The dramatic savings from this scenario are larger than any of the commercial scenarios, even the most optimistic, and thus clearly demonstrate the potential energy savings for an aggressive residential retrofit approach. A more modest variation is studied in scenarios T8 and T9, which respectively substitute advanced tungsten halogen infra-red technology, or CFLs for incandescent lamps which are used for 3 hours or more per day. The tungsten halogen IR scenario saves about ¼ of T6, and the CFL scenario saves about ½ of T6.

It should also be considered that the policies or market mechanisms that might support this scenario would simultaneously support the commercial scenario cT3, which assumes full CFL penetration in the commercial sector. The savings of the two scenarios would be completely additive. The yearly savings would increase by 33% and the cumulative savings by 36%.

## T7b Replace Floor and Table Lamps with Torchiers

This scenario assumes that the popularity of torchiers continues to increase, resulting in twice as much wattage for floor lamps in bedrooms and living rooms. Given the high wattage of current torchier lamps over standard incandescent floor or table lamps (300-500 watts vs. 75-150 watts), this seems an appropriate and even conservative assumption.

This scenario attempts to quantify what is viewed by some as a disturbing trend in residential lighting purchases by homeowners. Torchier fixtures are now widely available at very low cost, and they appear to be displacing traditional floor and table lamps in the marketplace. This scenario does assume an increase in lumen output due to the increased number of lamps. Basically, the statewide wattage of floor lamps is assumed to double over the 15 year period.

This scenario was found to increase installed watts by 1,000 megawatts and use an additional 689 gigawatthours per year in the year 2010. This is equivalent to increasing the statewide lighting load by 501,000 homes, or increasing the lighting energy use by 404,000 homes. Over 15 years it is projected to use an additional 4,306 gigawatthours of energy.

This increase is 2 to 20 times more than any savings projected from the residential new construction scenarios. This increase would essentially cancel ½ to 1/3 of the savings from the Energy Star outdoor lighting scenario (T1) or that of installing tungsten halogen IR lamps in all fixtures operating 3 or more hours per day (T8 below).

It should also be noted, that the increase in demand from use of additional torchiers is likely to directly increase residential peak loads, as illustrated above in Figure 3-2.

### T8 Replace Long Burning Incandescent Lamps with Tungsten Halogen Infrared Technology

This scenario assumes that lamps in those fixtures which are on for more than 3 hours per day are replaced with an improved tungsten halogen lamp with an efficacy of 22 lumens per watt. In order to approximate the proportion of fixtures operating for more than 3 hours per day, the rate of penetration was varied by fixture type, from 10% to 75%, depending upon the fixture's observed average hours of operation. For example, large table lamps which average 1.99 hours per day were assigned a 20% penetration level, while outdoor ceiling fixtures which average 3.10 hours per day were assigned a 50% penetration. The overall average penetration rate for all fixtures was about 25%. The scenario uses late penetration.

This scenario has to assume that a consumer education campaign is successful at helping homeowners understand where to apply this new technology, so that the new lamps are indeed installed in the fixtures which average 3 or more hours of operation per day.

This scenario was found to reduce installed watts by 2,438 megawatts and save 2,299 gigawatthours per year in the year 2010. This is equivalent to reducing the statewide lighting load by 1,222,000 homes, or reducing the lighting energy use by 1,349,000 homes, or 11.8% of current residential lighting energy use. Over 15 years it is projected to save approximately 13,843 gigawatthours of energy.

The magnitude of savings from this scenario is of the same order as those from lowering commercial Title 24 LPD requirements by an additional 20% (cN8) or removing all incandescents from commercial buildings (cN6). Alternatively, the savings are 5-50 times those of the residential new construction scenarios. The savings are 55% of those achieved with the CFL replacement described in T9 below.

### T9 Replace Long Burning Incandescent Lamps with CFLs

This scenario follows the same format as T8 above, but instead replaces long-burning incandescents with compact fluorescents (CFLs) instead of tungsten halogen IR lamps. The resulting savings are almost doubled.

This scenario was found to reduce installed watts by 4,373 megawatts and save 4,168 gigawatthours per year in the year 2010. This is equivalent to reducing the statewide lighting load by 2,192,000 homes, or reducing the lighting energy use by 2,446,000 homes, or 21% of current residential lighting energy use. Over 15 years it is projected to save approximately 25,100 gigawatthours of energy.

This scenario provides 52% of the energy savings of the residential scenario (T6) which involved replacement of 75% of incandescent lamps, but this scenario only replaces about 25% of existing incandescents. Alternatively, the magnitude of yearly savings from this scenario is equivalent to the commercial scenario (cN10) of installing maximum efficiency lamps and ballasts in all commercial floor space.

It should also be considered that the policies or market mechanisms that might support this scenario would simultaneously support the commercial scenario cT3, which assumes full CFL penetration in the commercial sector. The savings of the two scenarios would be completely additive. The yearly savings would increase by 64% and the cumulative savings by 68%.

### *3.1.3 Combined Residential Scenarios*

The additive effects of combining scenarios was looked at in a three cases where they seemed logically to make sense.

**N1, N4 & N5: T-24 Standards for Kitchens, Bathrooms and Outdoor Lighting**

This scenario assumes fluorescent lighting for most kitchen ceiling fixtures and bathroom vanity fixtures, and 50% of outdoor fixtures using fluorescent sources by changing the requirements and enforcement for Title 24 standards for residential new construction. It models the energy impacts of a more rigorous interpretation of current Title 24 standards for kitchens and bathrooms, and 50% of outdoor fixtures using fluorescent sources.

The results of this scenario are graphed in Figure 3-4 and Figure 3-5.

**N1, N3, N4, & N5: T-24 Standards for all NEC Required Fixtures**

This scenario is very similar to the one above, except that it models the energy impacts of having all residential fixtures required by the National Electric Code (NEC) be required to use efficient sources. Thus, porch lights, garage, basement, and attic lights, all ceiling fixtures in bathrooms, kitchens, hallways, stair ways, and utility rooms would use fluorescent sources, along with many ceiling mounted fixtures in bedrooms and living rooms. This is not a precise model of these conditions, but approximates the impacts.

By combining the effects of a number of scenarios, the energy effects are greatly increased, making it the most aggressive of the residential new construction scenarios. The installed watts reduction are doubled from N1 (ceiling fixtures), and the energy savings more than doubled.

The results of this scenario are graphed in Figure 3-4 and Figure 3-5.

### T1 & T2: Appliance Standards for Portable and Outdoor Lighting

This scenario looks at the impact of instituting appliance standards for both portable lighting fixtures and outdoor lighting fixtures for the residential market. The installed wattage reduction and the energy savings are slightly less than 80% of the impacts of T9: CFLs installed in all fixtures operating for 3 hours or more per day. They are 5 to 6 times greater than the second, most aggressive, combined new construction scenario presented above.

Figure 3-6 and Figure 3-7 below compare the results of this combined all-building scenario to others.

## 3.2 General Residential Conclusions

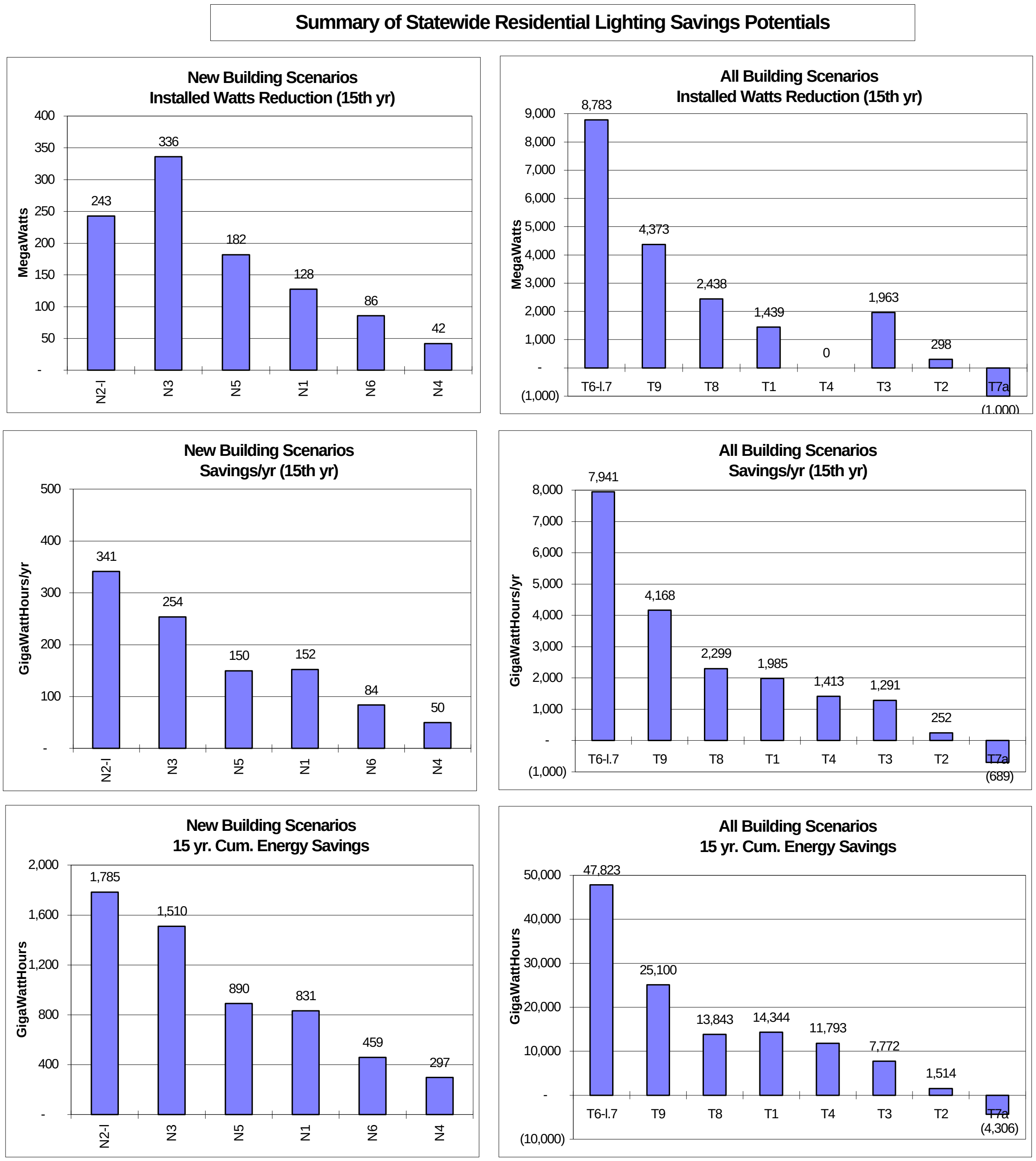
It is clear from this analysis that interventions which effect the entire residential market, such as marketing campaigns or appliance standards, have vastly greater impact than approaches that only effect new construction, such as Title 24 requirements. While it is true that homes are continually retrofitted, they are primarily retrofitted through the consumer market rather than a construction process that involves any code review.

Thus, this large potential for change from residential retrofits is best effected through appliance standards or a market based approach, rather than building standards. While the new construction scenarios have the ability to save from about 0.5 to 1.5% of current residential lighting energy use, the “all building” residential scenarios have the potential to effect from 7 to 21% of current residential lighting energy use, or about a 14 times larger impact.

It is also clear that current trends in increased energy use for lighting, such as the increased use of powerful halogen torchiers, could reduce any gains from a new construction approach to lighting efficiency, and could severely reduce the gains from any appliance standards or market based approach.

Energy savings from the “all building” residential scenarios are on a par with those considered for commercial buildings. This equity in energy savings potential exists in spite of the fact that commercial lighting hours of operation are 4 times longer than residential. The equity in savings exists primarily because the residential sector is so large, with 3 times as much installed wattage as the commercial sector, and because residential lighting currently uses much less efficacious sources than commercial, and so there is much greater potential for savings from efficiency improvements.

The results of the basic residential scenarios are graphically summarized in Figure 3-3. The combined scenarios are presented in Figure 3-4 through Figure 3-7, with comparisons to some of the basic scenarios.




N1 - Fluorescent Outdoor Lamps (50% ms, s)
N2-I - Induction Outdoor Fix & Contrls (100% ms, l)
N3 - Fluorescent Ceiling Fixtures (100%, ms, e)
N4 - T-24 Kitchen Fl. Compliance (50/100%, e)
N5 - Fluorescent Bath Vanities (100% ms, l)
N6 - Garage & Utility Fl. & Controls (75% ms, s)
(X% ms = market share in 15th yr, penetration types: e=early, l=late, s=straight line, c= classic "s" curve, )

T1 - Energy Star Outdoor Fixtures (50% ms,s)
T2 - CFL Torchiers (80% ms, l)
T3 - CFL Floor & Table Lamps (80% ms, l)
T4 - Time Limiters (80% ms, l)
T6-I.7 - CFLs Everywhere ((75% ms, l)
T7a - More Torchieres, (double flr lamps, 50% ms, l)
T8 - TH-IR in 3+ Hr. Fixtures (variable ms, l)
T9 - CFLs in 3+ Hr. Fixtures (variable ms, l)

**Note:**
**New Building graphs on the left have much smaller scale than the All Buildings graphs on right**

*Figure 3-3 - Residential Scenario Results*

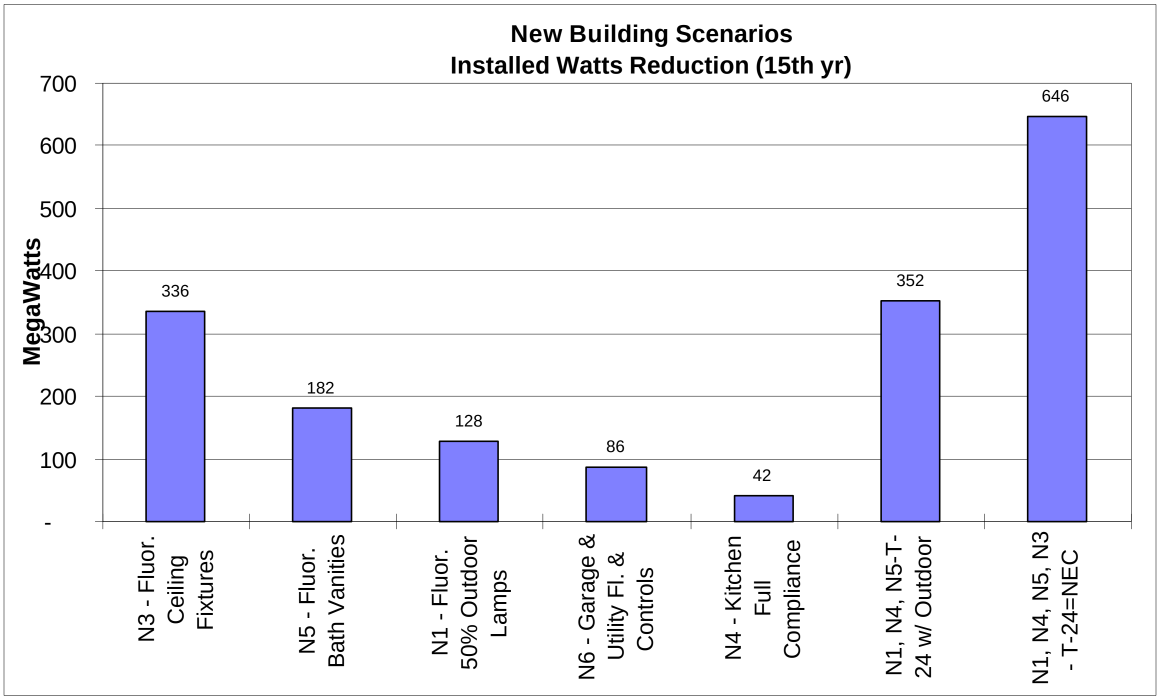



*Figure 3-4 - Combined Residential New Construction Scenarios, Install Watt Reduction*

Two combined residential new construction scenarios are compared. N1, N4 & N5 implies fluorescent lighting in kitchens, bathroom vanities, and outdoor lighting. N1, N3, N4, & N5 implies fluorescent lighting for all NEC required fixtures.

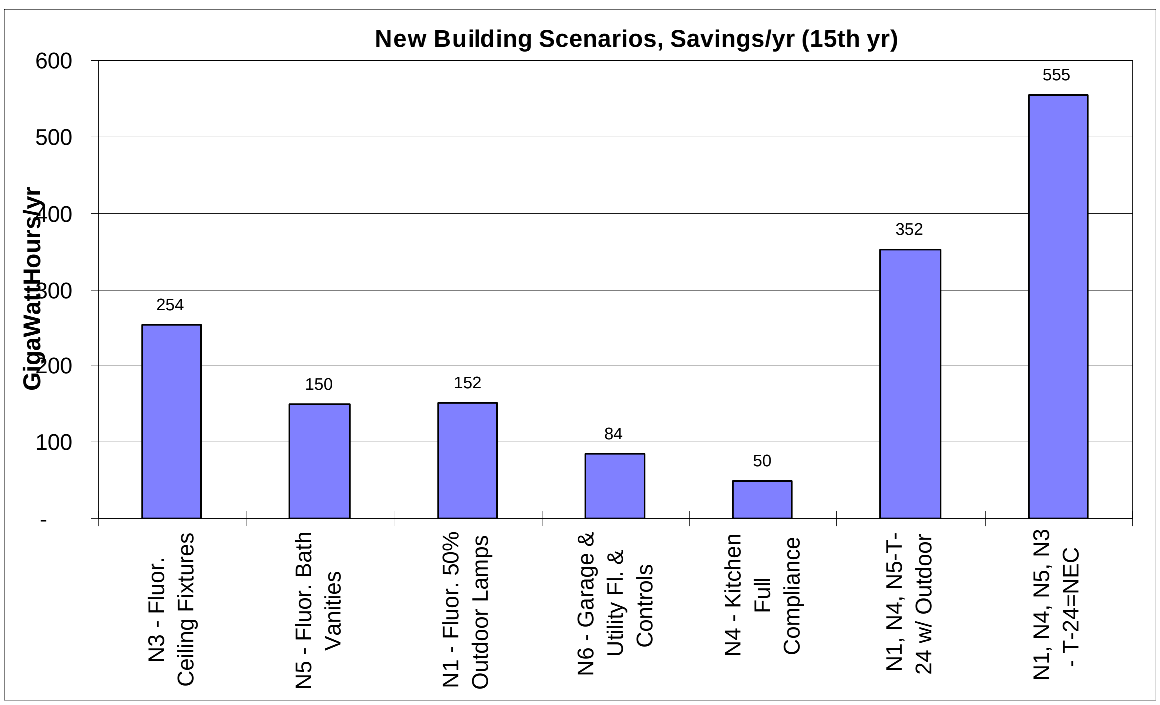



*Figure 3-5 - Combined Residential New Construction Scenarios, Energy Savings*

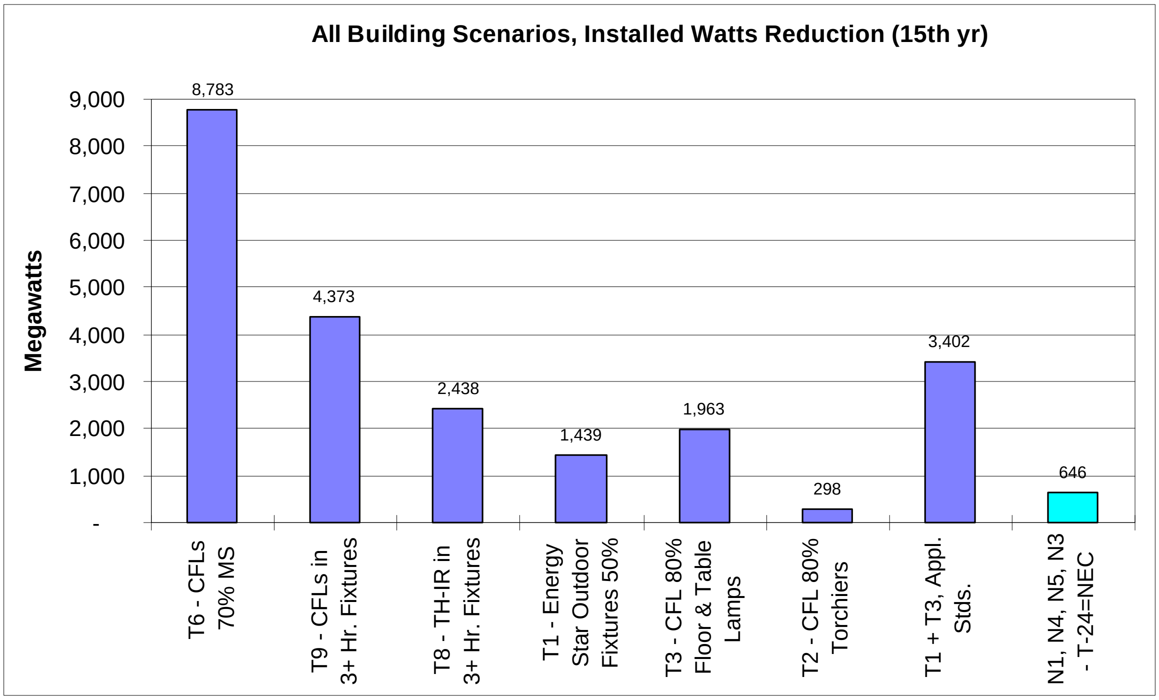



*Figure 3-6 - Combined Residential All Building Scenarios, Installed Watts Reduction*

A combined scenario (T1+T3), implying Energy Star standards for 50% of outdoor fixtures and 80% of portable fixtures, is compared to other residential all building scenarios, and the largest of the new construction combined scenarios.

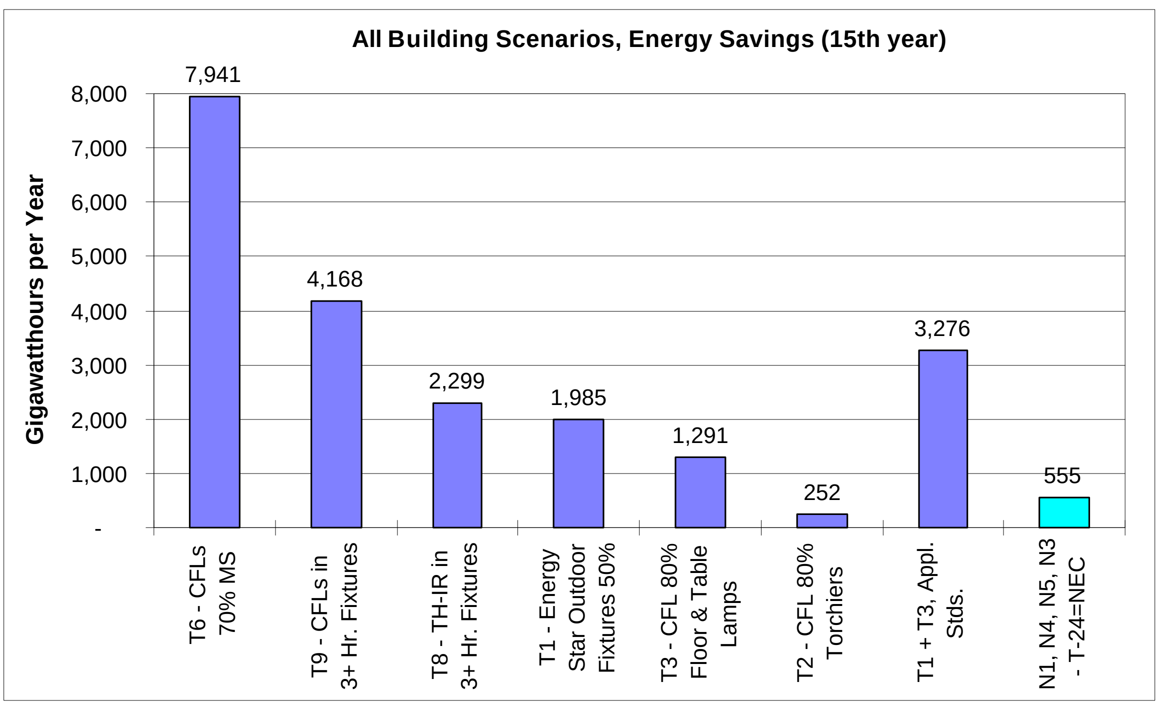



*Figure 3-7 - Combined Residential All Building Scenarios, Energy Savings*

# 4. COMMERCIAL LIGHTING

Please refer to the California Baseline Report, Volume I in this study, for information on commercial lighting baseline characteristics.

## 4.1 Commercial Scenarios

The following paragraphs provide a brief description of each of the commercial scenarios we have analyzed, followed by results and comments. They are presented first for scenarios effecting only the new construction which occurs during the 15 year study period. The second group are those scenarios which effect all of the existing commercial building stock plus new construction during the 15 year study period. The energy impact of the commercial scenarios are summarized in the graphs Figure 4-9 through Figure 4-15 in at the end of this section.

The designator code at the beginning of each scenario title is used as a short hand reference; it is included here for consistency and convenience. The assumptions for each scenario are described briefly here. The full detail for the assumptions for each scenario are included in the Scenario Specifications in the Appendix to this report.

### *4.1.1 New Construction Scenarios*

Once the baseline was constructed, alternative scenarios were studied in the model, using a 15 year study period. The following paragraphs provide a brief description of each of the commercial scenarios we have analyzed, followed by results and comments. The designator code at the beginning of each scenario title is used for our internal analysis purposes; it is included here for consistency and convenience.

The scenarios could either change the lumen shares of a given technology within a space, or could change the “lumen target” for that space. Changing the relative proportion of lumen shares for a set of technologies was used to model a change in market penetration for those technologies. For example, we changed technologies in scenario cPN1 where we assumed that the lumen share of T-12 and T-10 lamps, and magnetic and hybrid ballasts, all declined to 0% over a 15 year period, while T-8 lamps with electronic ballasts took over that portion of the market. Lighting levels remain constant.

The lumen target method was not meant to simulate a change in lighting levels. Rather, it was used as a somewhat indirect way to calculate a reduction in lighting power levels due to an assumed increase in efficacy, without making any assumptions about changes in technology. In terms of energy use calculations, reducing the lumen target is equivalent to reducing the installed wattage by the same percentage. For example, we used the lumen target method in scenario cN8 to calculate the lumen targets per space type that would be equivalent to a 20% reduction in allowed Title 24 lighting power density (LPD) levels.

## cN1 Improve Design Standards

This scenario assumes that lighting designers are trained to use more efficient luminaires, more efficient layouts and more efficient overall design strategies which deliver more of the lamps' lumen output to the task surface and/or optimize the use of light. This allows the lamp lumen output to be reduced by 10% on average for all space types in new construction. A classic penetration curve is assumed.

This scenario estimates an effect that might be achieved through an aggressive statewide education program for lighting designers, or a certification program that would increase the professional level of those hired to perform lighting design. The form of this program is open for discussion, as is the magnitude of the savings that could be achieved.

This scenario was found to reduce installed watts by 543 megawatts and save 1,772 gigawatthours per year in the year 2010. This represents a 10% reduction in new construction lighting energy use intensity and installed wattage. Over 15 years it is projected to save approximately 9,644 gigawatthours of energy.

## cN2 Improve Maintenance Practices

This scenario assumes that building owners and managers are trained about lumen maintenance and lighting system maintenance practices, and that they improve their practices so that lighting designers can design with smaller safety factors. This allows the initial lamp lumen output to be reduced by 5% on average, for all space types in new construction. A classic penetration curve is assumed.

This scenario estimates an effect that might be achieved through a statewide improvement in maintenance practices by building owners and/or operators, using improved provision of information on maintenance performance by the lighting industry.

This scenario was found to reduce installed watts by 271 megawatts and save 886 gigawatthours per year in the year 2010. This represents a 5% reduction in new construction lighting energy use intensity and installed wattage. Over 15 years it is projected to save approximately 4,822 gigawatthours of energy.

## cN3 Skylights and Photocontrols

This scenario assumes that the use of skylights and daylighting controls increases to 50% of new construction. Photocontrols are assumed to reduce the hours of lighting operation by 25% in all spaces except cooking, public and lodging. A late penetration curve is assumed.

This scenario presumes an education campaign that teaches owners and architects to install skylights in 50% of new construction. Currently, 90% of California commercial buildings are one-story, and an additional 5% are two-story buildings, implying a large potential for skylight use.

The 25% reduction in operating hours was derived by assuming a year-long average of 50% reduction in lighting power during six daylight hours, and factoring in a 5 to 7 day week of daylight hours into the observed hours of operation by building type. The 50% average yearly reduction in lighting power was based on the number of cloudy and sunny days in Sacramento, with a 15% minimum power level during full daylight, and 100% power during cloudy days. Although crude, we feel that this calculation provides a conservative and achievable estimate of savings potential.

This scenario did not reduce any installed wattage, and yet saves 1,133 gigawatthours per year in the year 2010. This is a 7.6% reduction in new construction lighting energy use intensity. Over 15 years it is projected to save approximately 5,857 gigawatthours of energy.

Skylighting does not reduce the installed wattage for a lighting system. In practice, skylighting can significantly reduce peak demand, since sky lighting is most available during most utilities' peak period—late afternoon on a sunny day. In addition, corresponding reductions in cooling loads from reduced electric lighting can continue to reduce peak loads even after sundown. This is of course true for the energy savings from all of the commercial lighting scenarios. However, our data does not allow us to distinguish any effects of time of use, climate or building specific effects.

## cN5 Unconditioned Space Included in T-24

This scenario assumes that Title 24 requirements for lighting system efficiency are extended to cover unconditioned spaces, such as warehouses and storage buildings. This is modeled by assuming a 10% drop in overall lumen output generated in these spaces, corresponding either to improved lighting equipment that more efficiently delivers the lumens produced, or to actual reductions in lumens delivered (cases of overlighting). A classic penetration curve is assumed.

Available data shows that current average usage in unconditioned storage spaces is 0.54 W/sf and miscellaneous unconditioned spaces average 0.90 W/sf. Title 24 tailored method allowances for illuminance categories B through D for large cavity spaces vary from 0.4 W/sf to 1.2 W/sf. Further, the data show that these spaces are lit primarily by full size fluorescents and HID sources. Thus, they appear to be quite efficient already, with only modest potential for improvement in efficiency from extending existing Title 24 requirements.

This scenario, as modeled, reduced installed watts by 83 megawatts and saved 300 gigawatthours per year in the year 2010. This is a 1.7% reduction in new construction lighting energy use intensity and a 1.5% reduction in installed wattage. Over 15 years it is projected to save approximately 1,631 gigawatthours of energy. These savings are the second smallest of the commercial scenarios.

On the other hand, relatively long hours of operation for these spaces increases the impact of energy savings, improving cost effectiveness. The market barriers for extending Title 24 lighting provisions to these unconditioned spaces should be quite low. They were originally exempted from Title 24 because no heating or cooling energy was involved. However, such as exclusion creates an anomaly for lighting practice.

## cN6 Outlaw Incandescents

This scenario assumes that all incandescent lighting in new buildings is replaced by compact fluorescents or by HID sources (for the high wattage lamps). It assumes 100% penetration and an early penetration curve.

This scenario presumes an extreme case, where incandescent lighting is outlawed in new buildings through some form of regulation. The scenario sets an upper limit on the savings potential from such a change.

This scenario was found to reduce installed watts by 823 megawatts and save 2,274 gigawatthours per year in the year 2010. This is a 10.9% reduction in new construction lighting energy use intensity and a 12.8% reduction in installed wattage. Over 15 years it is projected to save approximately 13,655 gigawatthours of energy. The proportionately greater demand savings from this scenario reflect the high wattage but shorter average hours of incandescent lamps. The demand savings are similar to cPN1, switching all fluorescent lamps to T8/electronic ballast technologies. The energy savings are similar to that of reducing Title 24 by 20% in scenario cN8.

## cN7 Reduce T-24 LPD Levels by 10%

This scenario assumes that Title 24 lighting power density allowances are reduced by 10%. A classic penetration curve is assumed. This effect is modeled by reducing the overall lumen target (a proxy for lighting power density in our model) for those space types which show average installed lighting power at current Title 24 levels or above. These include offices, hallways, dining areas, lodging, storage and miscellaneous. Other space types (such as retail, classrooms or public) are already 10% or better below Title 24, on average, and so are not changed.

This scenario presumes a modest across-the-board adjustment to Title 24 efficiency levels. Its effect is limited because many space types are shown to be better already than Title 24, on average. It provides a useful benchmark for comparison to other scenarios.

This scenario reduced installed watts by 225 megawatts and save 728 gigawatthours per year in the year 2010. This is a 4.1% reduction in new construction lighting energy use intensity and a 4.2 % in installed watts. Over 15 years it is projected to save approximately 3,953 gigawatthours of energy. It is the third smallest commercial scenario modeled in terms of its impact. The yearly demand reduction is on the same order of magnitude as the two largest residential new construction scenarios (N2 + N3), but the yearly and cumulative energy savings are 2-3 times as large, due to the much longer hours of operation for the commercial sector.

## cN8 Reduce T-24 LPD levels by 20%

This scenario, an extension of the previous one, assumes that Title 24 LPD allowances are reduced by 20%. A classic penetration curve is assumed. This effect is modeled as in scenario cN7 above. Because this is a more substantial reduction than the previous scenario, nearly all space types are affected. Only four space types (technical, public, industrial and unconditioned miscellaneous) are already 20% or more below Title 24 requirements.

This scenario presumes a more ambitious across-the-board adjustment to Title 24 efficiency levels. It provides a second useful benchmark for comparison to other scenarios.

This scenario reduced installed watts by 707 megawatts and save 2,281 gigawatthours per year in the year 2010. This is a 12.9% reduction in new construction lighting energy use intensity and a 13.0 % in installed wattage. Over 15 years it is projected to save approximately 12,418 gigawatthours of energy. The yearly energy savings is on the same order of magnitude as the third largest residential all building scenario (T8-tungsten halogen IR lamps), but the wattage reductions are 1/3 as large, due to the much longer hours of operation for the commercial sector.

### cPN1 Full Penetration of T-8/Electronic Ballasts

This scenario assumes that all 4' and 8' standard fluorescents are changed to T-8 lamps and electronic ballasts for new construction. A classic penetration curve is assumed.

This scenario estimates the maximum likely savings from this change in technology, which is already well underway in the marketplace.

This scenario reduced installed watts by 827 megawatts and saved 2,776 gigawatthours per year in the year 2010. This is a 13.6% reduction in new construction lighting energy use intensity and a 13.2% reduction in wattage. Over 15 years it is projected to save approximately 16,580 gigawatthours of energy. It is interesting that the demand savings for this scenario are 17% greater, and the energy savings 22% greater, than the previous scenario with 20% reduction in Title 24 LPD requirements. This means that converting all fluorescents in commercial buildings to T8/electronic ballast technology over a 15 year period is likely to save more energy that uniformly lowering the Title 24 standards by 20%.

### cPN2 Add Lumen Maintenance Controls to cPN1

This scenario is an extension of the previous scenario. It assumes dimming ballasts and lumen maintenance controls achieve 50% market penetration. These controls, when applied to T-8 lamp technology, are assumed to achieve a 5% power reduction on average (T-8 lamps already have good lumen maintenance characteristics of about 90% over their life).

This scenario assumes an increased market penetration of this control technology, due to increased availability and reduced cost of electronic dimming ballasts and photo sensing controls.

This scenario reduced installed watts by 900 megawatts and saved 3,204 gigawatthours per year in the year 2010. This is a 15% reduction in new construction lighting energy use intensity and a 14.6% reduction in wattage. Over 15 years it is projected to save approximately 17,935 gigawatthours of energy. This scenario, with the addition of dimming ballasts and lumen maintenance controls, provides an additional 9% in energy savings over the previous T8/electronic ballast scenario. This translates into an additional 1.5% in statewide energy savings.

## *Progressive Scenarios*

The following five scenarios, cN9 - cPN13, take a progressive approach for assessing additive savings from a combination of strategies. Many of the simple scenarios could be pursued simultaneously, however their savings are not strictly additive because they are interdependent. These five scenarios look at a logical approach for how scenarios could be combined. All of them incorporate technology which is currently commercially available. Those with greatest singular savings were run first, with those with lesser savings added in sequence. Taken together they can be used to define the full potential of lighting savings available using 1996 technology.

### CN9 New Technology Standard for Title 24

This scenario is similar to cPN1, which assigns T8/elelctronic lamp technology to all fluorescent lighting, but goes a few steps farther. It also assumes that all existing uses of compact fluorescent lamps are converted to electronic ballasts over the 15 year period, and that all existing uses of incandescent lamps are replaced with a tungsten halogen infrared level of lamp. Thus, these three lighting systems throughout are replaced with the more efficient technologies which are commercially available in 1995. This is similar to the approach that was originally used to generate the Title 24 standards using efficient technologies that were becoming commercially available at the time (circa 1987).

The results of this scenario allow us not only to look at the potential energy savings, but also to examine the resulting Watts/sf levels by building and space type, to compare to existing Title 24 requirements.

This scenario was found to reduce installed watts by 973 megawatts and save 3,077 gigawatthours per year in the year 2010. This is a 17.4% reduction in new construction lighting energy use intensity and a 18% reduction in wattage. Over 15 years it is projected to save approximately 16,717 gigawatthours of energy. It represents an 10.8% increase in savings over cPN1 (T8/electronic ballasts), and an 18% decrease in demand.

### cPN10 Maximum Efficacy Lamps and Ballasts

This second scenario of five goes the next step farther in assigning not a few new technologies, but the most efficient technology throughout. Thus, in addition to three technologies changed in the last scenario, most incandescent applications are converted to compact fluorescent or HID lamps, depending on their size. The 50% of incandescents remaining in retail, dining, and public space types, and the 10% remaining in all other space types are converted to halogen IR technology. All compact fluorescents convert to using electronic ballasts and HID lamps use high efficiency ballasts. Classic penetration is assumed.

This scenario attempts to quantify the savings that could be achieved by using the most efficient lamp/ballast technology throughout commercial buildings.

This scenario was found to reduce installed watts by 1,435 megawatts and save 4,340 gigawatthours per year in the year 2010. This is a 23.7% reduction in new construction lighting energy use intensity and a 25.4% reduction in wattage. Over 15 years it is projected to save approximately 24,022 gigawatthours of energy. This represents a 41% increase in energy savings over the previous cPN9 scenario, and 56% greater energy savings than the cPN1 (T8/electronic ballasts only).

### cPN11 Maximum Efficacy Plus Improved Design

This scenario builds on the previous, by assuming all of the efficacious light sources describe above, used in combination with improved design methodology, as described in the first commercial scenario, cN1, Improved Design, which assumes that lighting designers are trained to use more efficient luminaires, more efficient layouts and more efficient overall design strategies. Such design strategies, which optimize the use of light, allow the lamp lumen output to be reduced by 10% on average for all space types in new construction.

This scenario was found to reduce installed watts by 1,872 megawatts and save 5,791 gigawatthours per year in the year 2010. This is a 31.3% reduction in new construction lighting energy use intensity and a 32.9% reduction in wattage. Over 15 years it is projected to save approximately 32,222 gigawatthours of energy. It represents a 33% increase in savings over the previous cPN10 scenario for maximum lamp/ballast efficacy.

### cPN12 Maximum Efficacy Plus Improved Design and Controls

This scenario builds on the previous scenario, using all the same assumptions, and adding occupancy sensors per cT1. It assumes that 50% of all on/off switches, in all space types except retail, are converted to occupancy sensors (or an equivalent automatic control technology). The controls are assumed to reduce hours of lighting by applying a correction factor of 70-95%, depending upon the space type. These factors, provided in Figure 4-1, were based on a combination of observing the existing market share of occupancy sensors in these space types, and on professional judgment.

| Space Type | Correction Factor | Space Type | Correction Factor |
|---|---|---|---|
| Office | 90% | Public | 80% |
| Hall | 95% | Lodging | 70% |
| Retail | 100% | Storage-C | 70% |
| Dine | 90% | Storage-U | 70% |
| Cook | 90% | Industrial | 90% |
| Tech | 90% | Misc-C | 90% |
| Class | 85% | Misc-U | 90% |

*Figure 4-1 - Occupancy Sensor Correction Factors, by Space Type*

This scenario was found to reduce installed watts by 1,872 megawatts and save 6,260 gigawatthours per year in the year 2010. This is a 33.7% reduction in new construction lighting energy use intensity and a 32.9% reduction in wattage. Over 15 years it is projected to save approximately 34,932 gigawatthours of energy. The wattage reduction is the same as the previous scenario. The energy savings increase by 8%.

### cPN13 Maximum Efficacy Plus Improved Design, Controls and Skylighting

This scenario builds on the previous scenario, using all the same assumptions, and adding skylighting and dimming controls to the other 50% of new construction which does not include the occupancy controls, per cN3. The area with skylighting and dimming controls has a 25% reduction in operating hours.

This scenario was found to reduce installed watts by 1,872 megawatts and save 7,468 gigawatthours per year in the year 2010. This is a 39.9% reduction in new construction lighting energy use intensity and a 32.9% reduction in wattage. Over 15 years it is projected to save approximately 41,841 gigawatthours of energy. This represents a 19% increase in energy savings over the previous scenario, and no reduction in installed wattage.

### cPN14 ASHRAE/IESNA 90.1R LPD

This scenario applies the proposed new ASHRAE/IESNA Standard 90.1R lighting power density (LPD) standards to California commercial buildings. Standard 90.1R is the new model energy code for commercial buildings that is currently under development. It is being developed by joint committees of the American Society of Heating, Refrigeration, and Air-Conditioning Engineers (ASHRAE) and the Illuminating Engineering Society of North America (IESNA). It is currently under review (2/97), and may be changed before it is formally adopted.

The current proposed ASHRAE standards were examined by space type, and when more than one ASHRAE space type was represented in a CLM model space type, it was given a weight corresponding to its approximate representation in the sample of the California commercial building stock used for this study. The average existing efficacy by space type was then used to convert the proposed Watts/sf to lumens/sf. The assumptions used in this conversion are shown in the detailed scenario specifications in the appendix to this report.

These proposed Standard 90.1R lumen/sf targets were then used to run the CLM model. The proposed ASHRAE/IESNA 90.1R standards were found to be higher than existing conditions in California buildings in four space types: Retail, Cooking, Technical, and Public.

This scenario was found to reduce installed watts by 403 megawatts and save 962 gigawatthours per year in the year 2010. This is a 5.4% reduction in new construction lighting energy use intensity and a 7.4% reduction in wattage. Over 15 years it is projected to save approximately 5,262 gigawatthours of energy. It saves slightly more energy than reducing Title 24 standards by 10% (cN8), and almost doubles the wattage reduction.

## cPN15 ASHRAE/IESNA 90.1r LPD Plus Controls

This scenario applies the proposed new ASHRAE/IESNA 90.1R lighting power density (LPD) standards to California commercial buildings, as in the previous scenario, and adds a factor for control savings.

The Standard 90.1R is currently proposing a variety of options for meeting the requirement automatic controls. It is unclear how these options would be selectively applied to various building or space types, and it is unknown what the resulting energy savings would be. California commercial buildings already have a considerable penetration of automatic controls, as found in the analysis of the baseline data. It is not clear how much more aggressive the proposed ASHRAE/IESNA control standards would be than already existing control levels. Thus, for lack of better information, a uniform 10% reduction in hours of operation was applied to all space types to model the potential of the new proposed control standards.

This scenario was found to reduce installed watts by 403 megawatts and save 2,662 gigawatthours per year in the year 2010. This is a 14.9% reduction in new construction lighting energy use intensity and a 7.4% reduction in wattage. Over 15 years it is projected to save approximately 14,587 gigawatthours of energy. The wattage reductions are the same as the previous scenario, but the energy savings are 2 and ¾ times greater.

### 4.1.2 All Building Scenarios

The following three scenarios look at a retrofit or market mechanism which impacts all commercial buildings, rather than just new construction. As a result, they initially impact a much large population than the new construction scenarios. As described earlier and illustrated in Figure 2-1, commercial new construction since 1995 represents 90% of buildings by 2010, thus there is less long term effect for these “all building” commercial scenarios than the “all building” residential scenarios.

#### cT1 Occupancy Sensors

This scenario assumes that 50% of all on/off switches, in all space types except retail, are converted to occupancy sensors. The occupancy sensors are assumed to reduce hours of lighting by applying a reduction factor of 70-95% depending upon the space type. These assumptions are detailed in Figure 4-1 for scenario cPN12 above. A straight line penetration curve is assumed.

This scenario presumes a dramatic increase in the use of these controls, and calculates a likely maximum practical penetration rate and reduction in average hours by space type. This might be achieved through education and reduced cost of the equipment; most likely it would require a regulatory intervention.

This scenario results in no wattage reduction, but 1,133 gigawatthours savings per year in the year 2010. This is a 3.6% reduction in new construction lighting energy use intensity. Over 15 years it is projected to save 5,857 gigawatthours of energy.

#### cT2 High efficiency HID and HPS

This scenario assumes an increase in the use of high efficiency HID ballasts, reducing the lumen share of standard ballasts by 50% with a late penetration curve. In addition, all but 10% of low pressure sodium and mercury vapor lighting is converted to high pressure sodium, with a straight line penetration curve.

This scenario presumes near future improvements in high efficiency HID ballasts that make them more cost effective and appropriate to at least half of current HID applications. It also presumes that the remaining 0.3% lumen share of low pressure sodium, and the remaining 7.4% lumen share of mercury vapor, transition to high pressure sodium sources which can make use of these more efficient ballasts. This might be achieved through market forces, but might also require a regulatory push.

This scenario as modeled reduced installed watts by 40 megawatts and saved 148 gigawatthours per year in the year 2010. This is a 0.5% reduction in commercial lighting energy use intensity and a 0.4 % in demand. Over 15 years it is projected to save approximately 1,412 gigawatthours of energy. It is the smallest savings of all the commercial scenarios.

### cT3 CFL Full Penetration

This scenario assumes that most small and medium incandescent lighting is converted to compact fluorescent. Most applications convert 90% of incandescent lumens to CFL, except for retail, dining and public spaces which convert 50%. A straight line penetration curve is assumed.

This scenario is similar to cN6, which eliminated all incandescents from new commercial buildings, except that this scenario is applied to "all buildings" via a retrofit mechanism rather than only to new construction via regulations, and this scenario assumes lower penetration levels. CN6 converts 100% of small and medium incandescents to CFLs, and 100% of large incandescents to HID. This scenario only converts 90% small and medium incandescents to CFLs for most space types, and only 50% for retail, dining, and public spaces.

This scenario was found to reduce installed watts by 879 megawatts and save 2,662 gigawatthours per year in the year 2010. This is a 7.1% reduction in commercial lighting energy use intensity and a 9% reduction in demand. Over 15 years it is projected to save approximately 17,048 gigawatthours of energy.

The yearly energy savings are essentially identical with cN6 (no incandescents), but the demand savings are slightly (6%) larger, and the cumulative savings over the 15 year period are 25% larger. This is the effect of a retrofit program penetrating (straight line) into the larger all building market, rather than a new construction program penetrating (early penetration) only into the new construction floor space each year.

This scenario might be supported by the same market efforts which would support parallel residential scenarios, T6, which assumes 75% of residential incandescents are converted to CFLs, or the more modest T9, which assumes that CFLs are retrofitted into residential fixtures which are operated for more than 3 hours per day. If the results of this scenario and T6 are added together, the resulting wattage reduction is 9, 660 megawatts and the yearly savings 10,600 gigawatthours per year, or almost a ¼ of current lighting energy use for both the residential and commercial sectors.

## 4.2 General Commercial Conclusions

### *4.2.1 Demand Impacts*

Installed Watts reduction for commercial scenarios are on a par with installed Watts reduction for the residential scenarios, ranging from 40 megawatts to 1,872 megawatts. (Residential scenarios range from 42 megawatts to 2,438 for most scenarios. The most extreme residential scenario, T6, predicts 8,783 megawatts of installed wattage reduction if 75% of residential incandescent lighting were converted to CFL.)

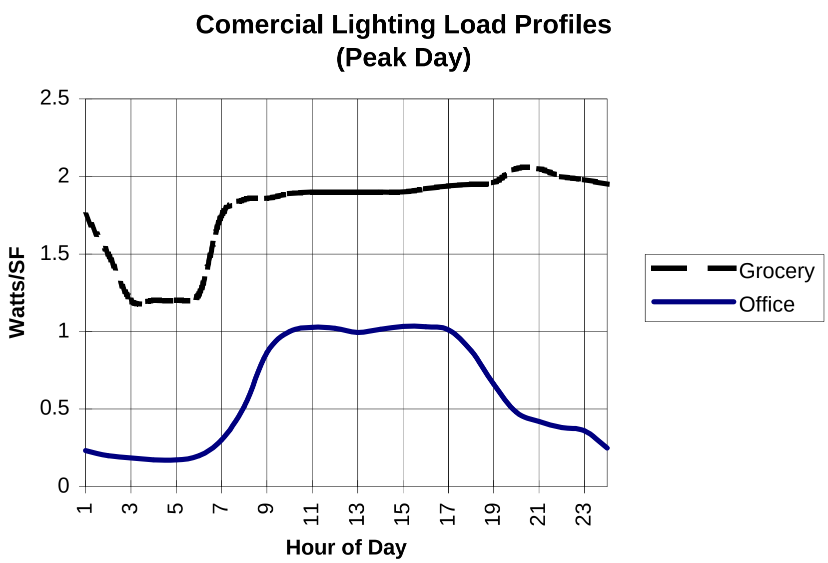



*Figure 4-2 - Commercial Lighting Load Profiles (Peak Day)*

Figure 4-2 shows the lighting load profile[1] for two commercial building types. While the pattern of these profiles varies considerably with building type, commercial lighting loads tend to very closely mirror occupancy, or hours of operation for a given building type. Since most commercial buildings are occupied during periods of peak demand (generally summer afternoons and evenings), reducing installed lighting wattage for commercial buildings directly reduces peak building electrical demand in most cases. Refer to discussion in section 2.3.1.

Al though end use profiles aggregated across building type are difficult to come by, EPRI has published assumptions about commercial lighting loads by building type, which have been used to generate the following chart in Figure 4-3. Based on the assumptions, the overall commercial sector lighting load is about 87% at

[1] ADM Associates, End-Use Metered Data for Commercial Buildings, for Southern California Edison, 1993

a 3PM summer peak, and 78% at a 6PM peak. The kWh weighted averages above were used to convert install commercial wattage to demand impacts for this report.

| Peak Lighting Demand | % load* | | vacancy | % load * vacancy | |
|---|---|---|---|---|---|
| | 3:00 PM | 6:00 PM | rate | 3:00 PM | 6:00 PM |
| GROCERY | 100 | 95 | 0.95 | 0.95 | 0.90 |
| HEALTH | 95 | 85 | 0.95 | 0.90 | 0.81 |
| LARGEOFFICE | 100 | 90 | 0.90 | 0.90 | 0.81 |
| LODGING | 100 | 98 | 0.95 | 0.95 | 0.93 |
| MISCELLANEOUS | 100 | 90 | 0.90 | 0.90 | 0.81 |
| RESTAURANT | 100 | 90 | 0.90 | 0.90 | 0.81 |
| RETAIL | 100 | 98 | 0.90 | 0.90 | 0.88 |
| SCHOOL | 100 | 75 | 0.70 | 0.70 | 0.53 |
| SMALLOFFICE | 100 | 90 | 0.90 | 0.90 | 0.81 |
| WAREHOUSE | 90 | 75 | 0.90 | 0.81 | 0.68 |
| | | | average | 0.88 | 0.80 |
| | | | Kwh weighted average | 0.87 | 0.78 |

*Figure 4-3 - Peak Lighting Load Percent by Building Type*[2]

Residential lighting profiles, in contrast, tend to peak at 7 to 8 PM in the summer, often after the utility system peak demand (see Figure 3-2 above). This means that residential lighting demand reductions are generally less valuable to utilities in their load management programs.

### 4.2.2 New Construction Energy Codes

The analysis shows that there is significant potential for energy savings and demand reduction in commercial lighting, without reducing current lighting levels. (This analysis uses the California commercial building stock circa 1992-1994 as the baseline.) Modest savings could be achieved by lowering Title 24 requirements by a uniform 10%, resulting in an average reduction of 0.06 Watts/sf for commercial space overall. However, reductions on the order of 0.45 Watts/sf for the whole building stock overall, or 7½ time greater than a 10% Title 24 reduction, are obtainable with existing technologies and design methods.

Converting fluorescent technologies to the equivalent of T8/electronic ballasts, a change that is already well underway in the marketplace, saves more energy and reduces wattage more than lowering Title 24 by a uniform 20%. This single change also has substantially greater impact than adopting the proposed ASHRAE/IESNA 901.R standards for commercial building lighting.

[2] EPRI, Lighting Handbook for Utilities pages 3-4, 3-5, April '86

The savings reaped from a conversion to T8/electronic ballasts can be doubled if all commercial lighting is converted to the most efficient alternative which is commercially available in 1996. An additional 68% in energy savings, and 28% reduction in wattage could be further achieved through other viable lighting efficiency methods such as careful lighting design, use of automatic controls and daylighting.

In addition to studying the impact of new construction energy codes by building type, we also looked at the relative impact of various scenarios by space type. The lighting power density impacts of seven scenarios are presented in the following 14 graphs, Figure 4-4 through Figure 4-8. It should be noted that these modeling results are estimates. The model base case was found to be accurate within ± 5% of the baseline analysis value. The methodology for generating a Title 24 or an ASHRAE/IES 90.1R equivalents involves many assumptions about the mix of building types within the sample and the code categories. (The calculations are documented in the Scenario Specifications included in the Appendix of this report.)

The graphs tell a very interesting story about the lighting power densities that are likely to result in the California building stock from various approaches to lighting efficiency. Some space types appear to have substantial room for improvement (such as public or retail) while others appear to be close to maximum efficiency (industrial, unconditioned storage). Space types with a large incandescent component (such as lodging) are not effected by simple fluorescent improvements (cN9). The three technology-based scenarios (cPN1, cN9, & cPN10) make it clear that the lowest LPDs can be reached without lowering any lumen levels from what they currently are in the overall California building stock.

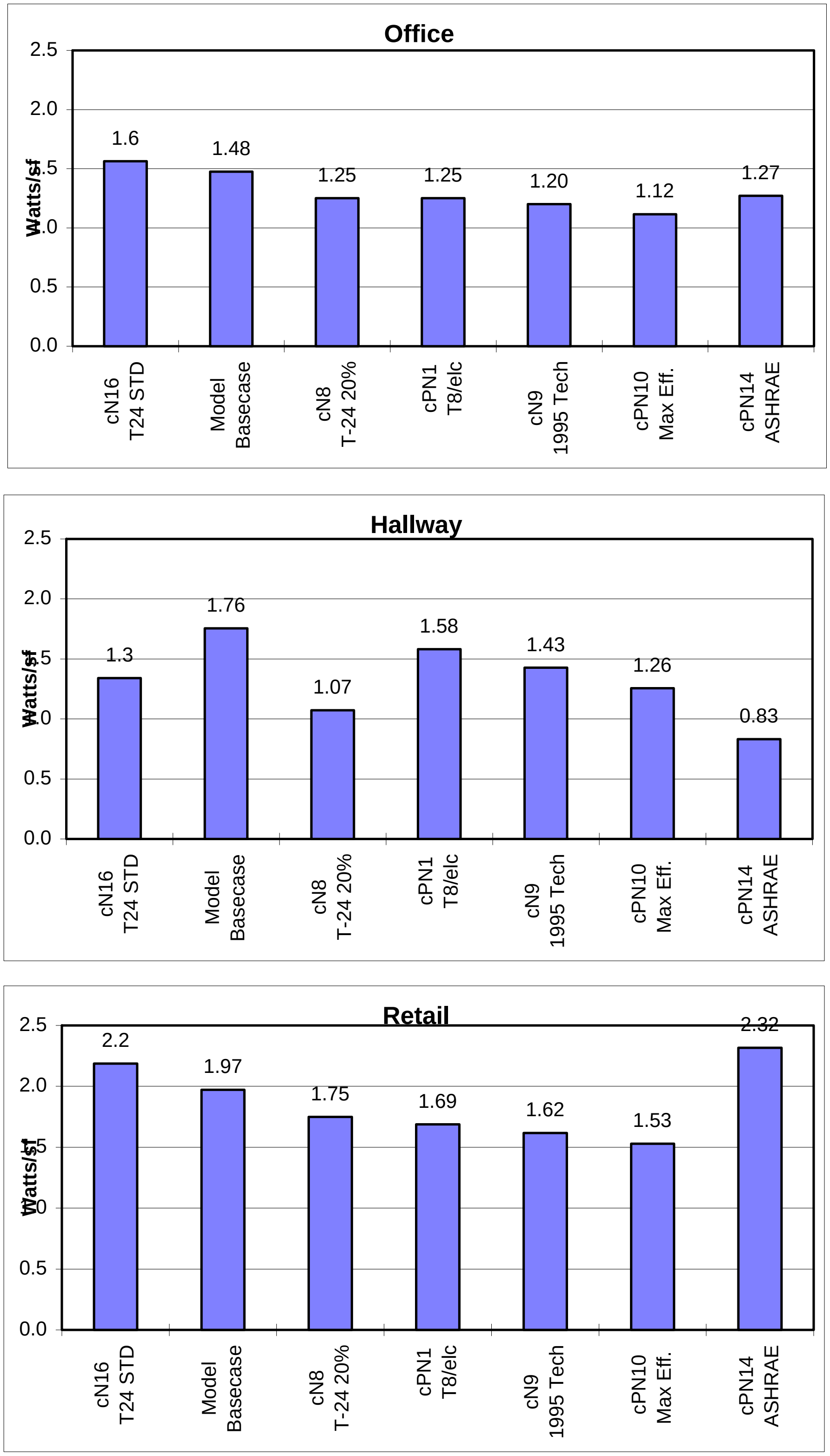
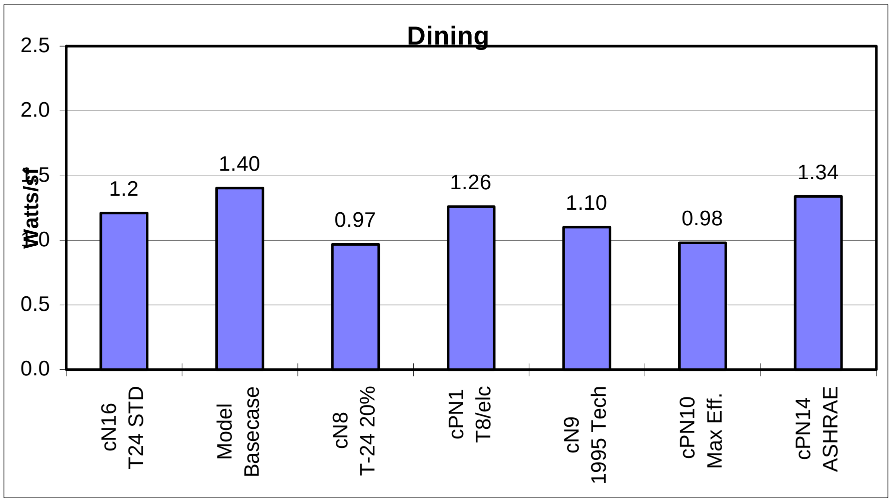
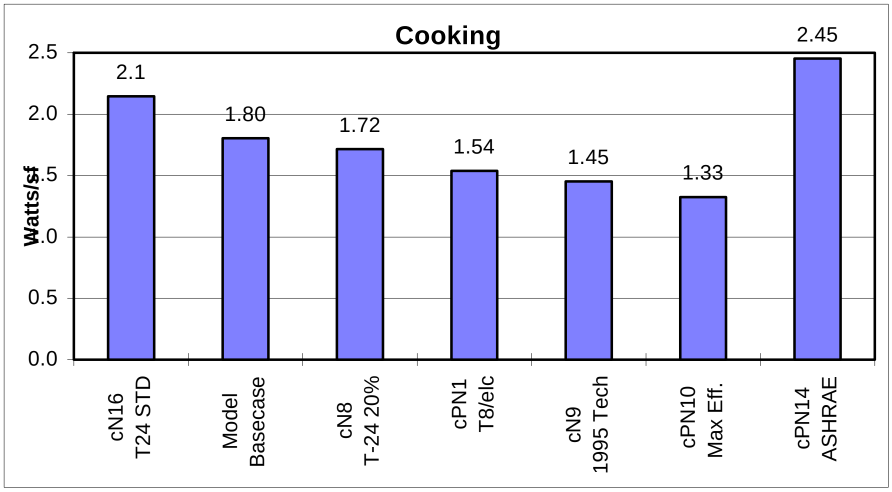



*Figure 4-4 - Office, Hallway, Retail Space Type LPDs*



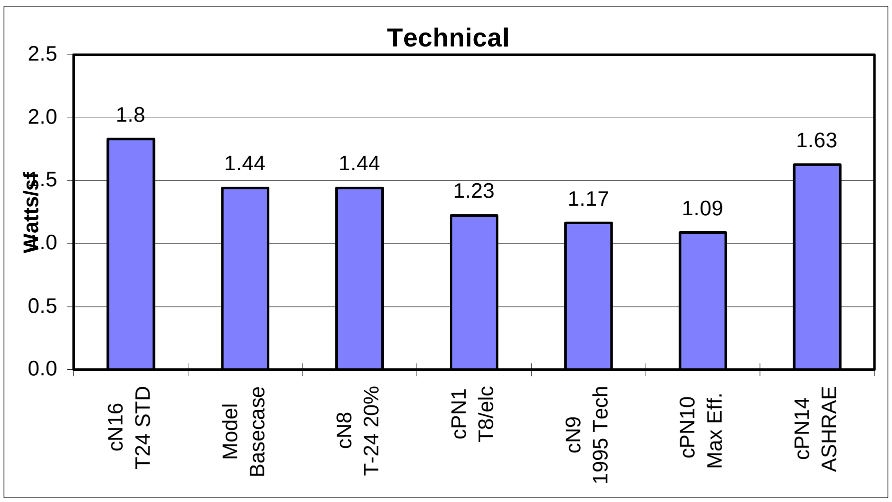
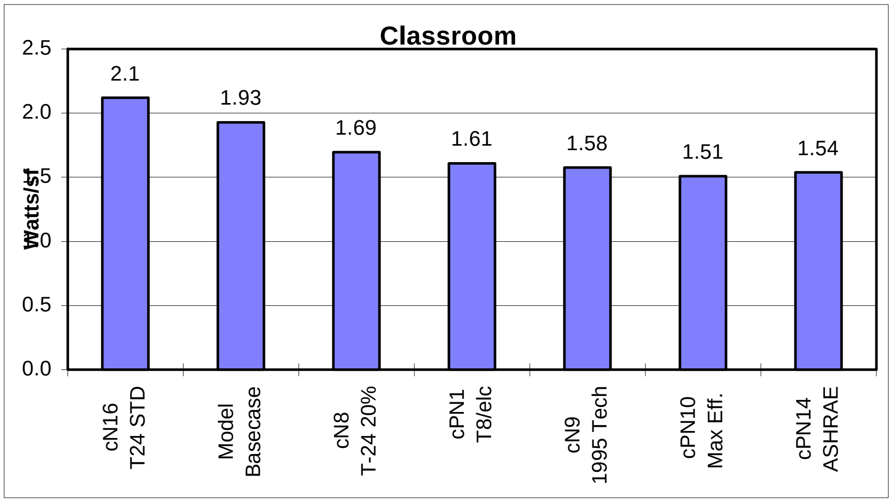
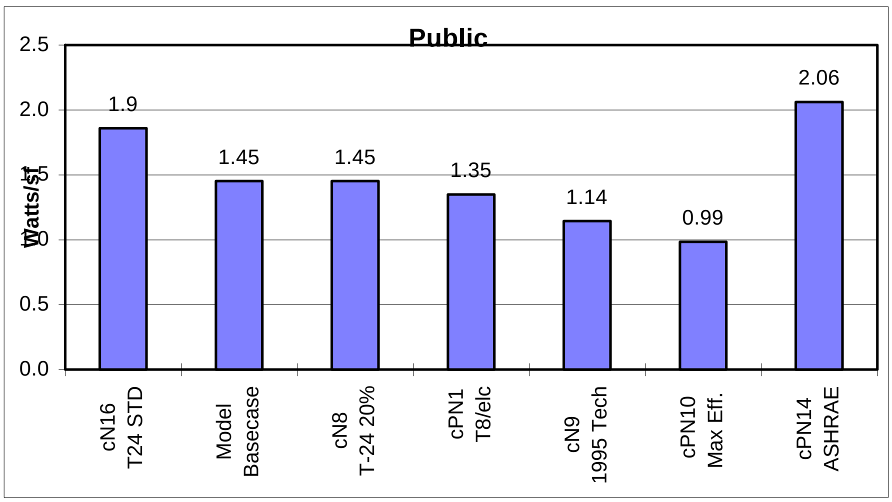




*Figure 4-5 - Dining Cooking, Technical Space Type LPDs*



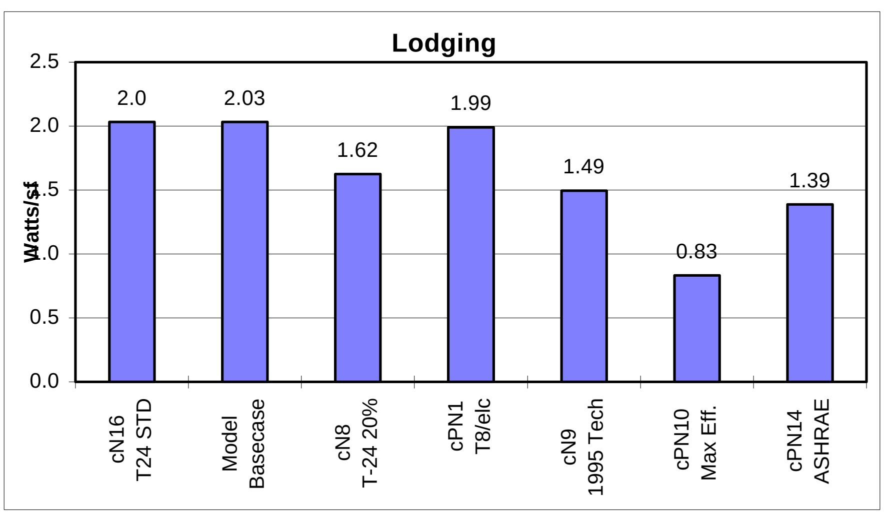
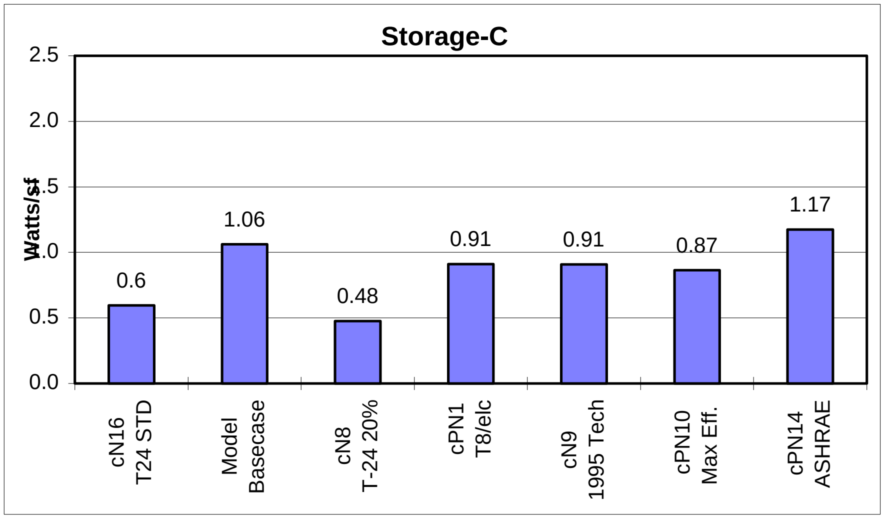
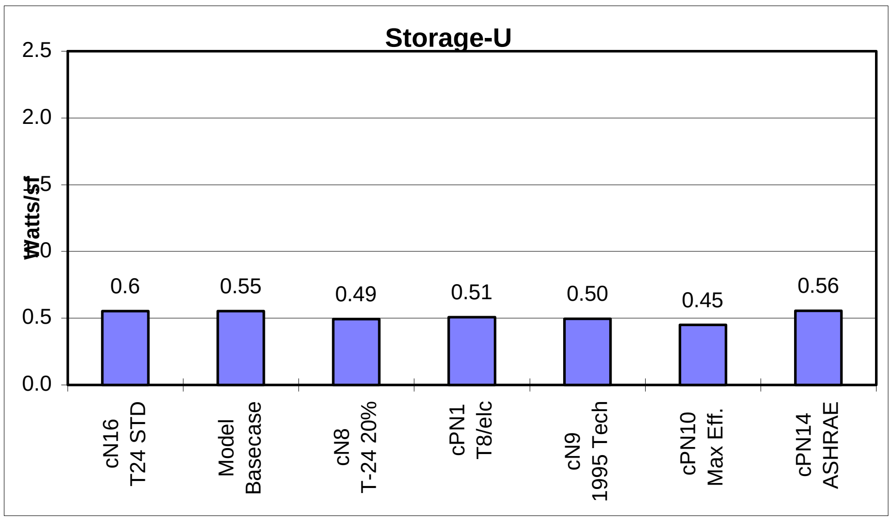




*Figure 4-6 - Classroom, Public Lodging Space Type LPDs*



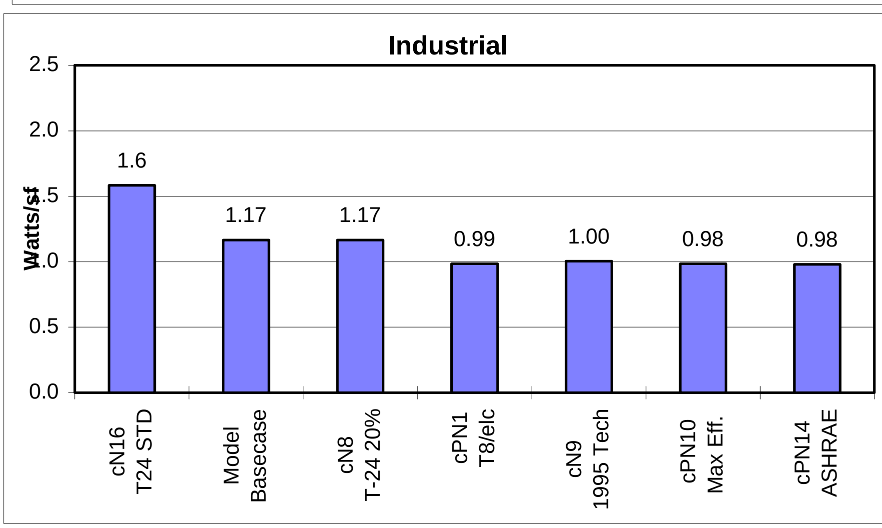
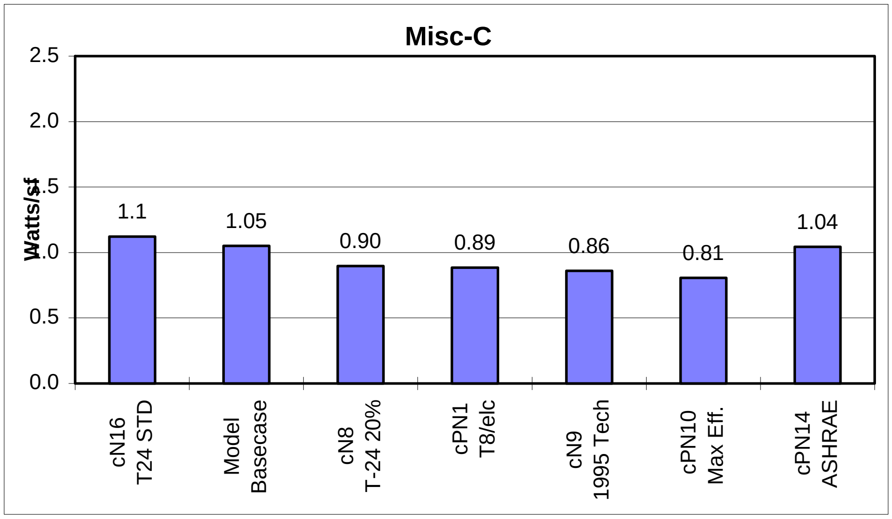




*Figure 4-7 - Storage-C, Storage-U, Industrial Space Type LPDs*



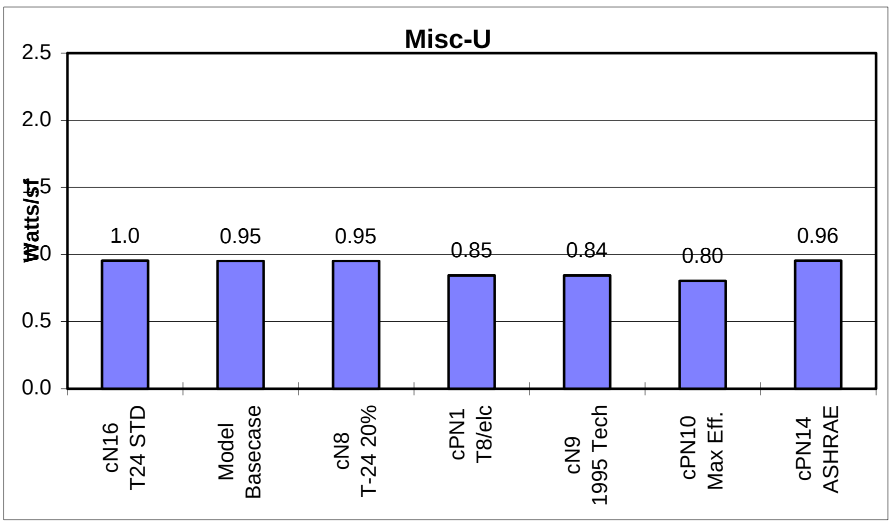




*Figure 4-8 - Misc-c, Misc-u Space Type LPDs*

It should be remembered that modeling results are presented here by space type. These space types, when aggregated into building types, will produce different overall lighting power densities by building type, which are presented below in Figure 4-12 - Installed Watts Reduction per sf - Commercial New Construction.

### 4.2.3 Commercial Scenario Results

Results of the commercial scenarios are presented in a variety of formats in the following seven graphs:

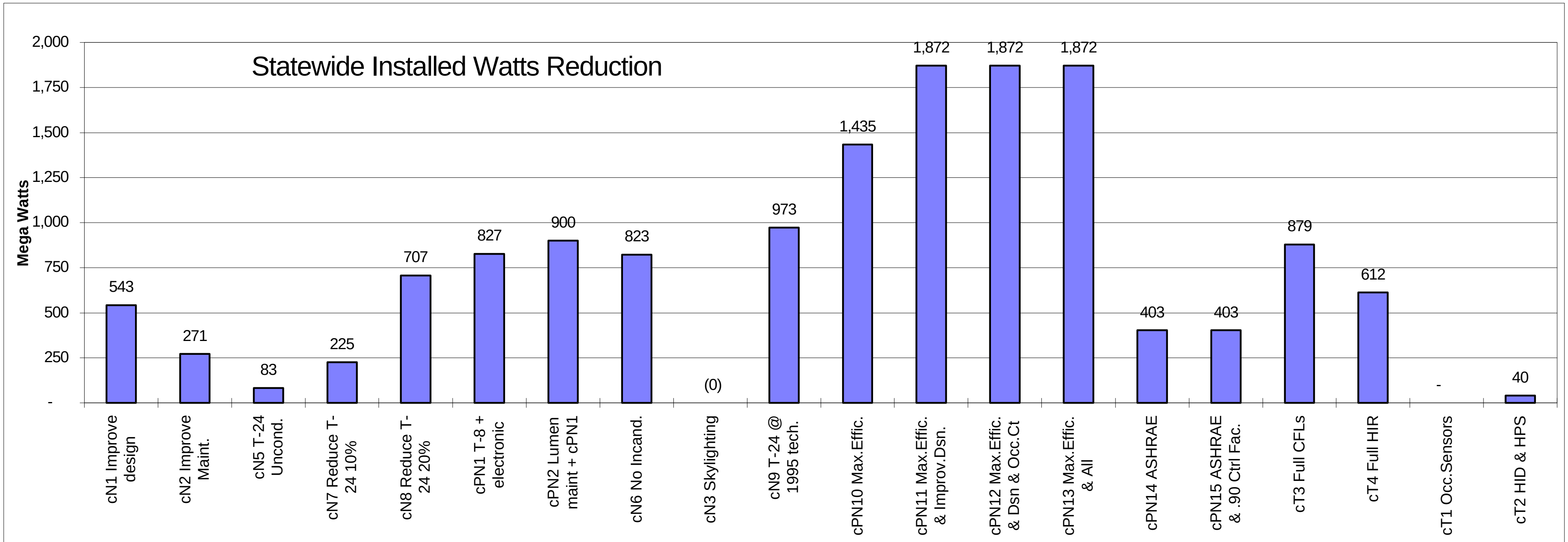



*Figure 4-9 - Statewide Installed Watts Reduction - All Commercial*

Figure 4-9 looks at the total reduction in installed watts compared to the baseline conditions, calculated for a given scenario. To give these numbers perspective, consider that current installed wattage for all lighting in all office buildings in California is about 2,000 megawatts. A new gas turbine power plant for a utility might produce 350 to 400 megawatts. An existing nuclear power plant produces on the order of 1,000 megawatts.

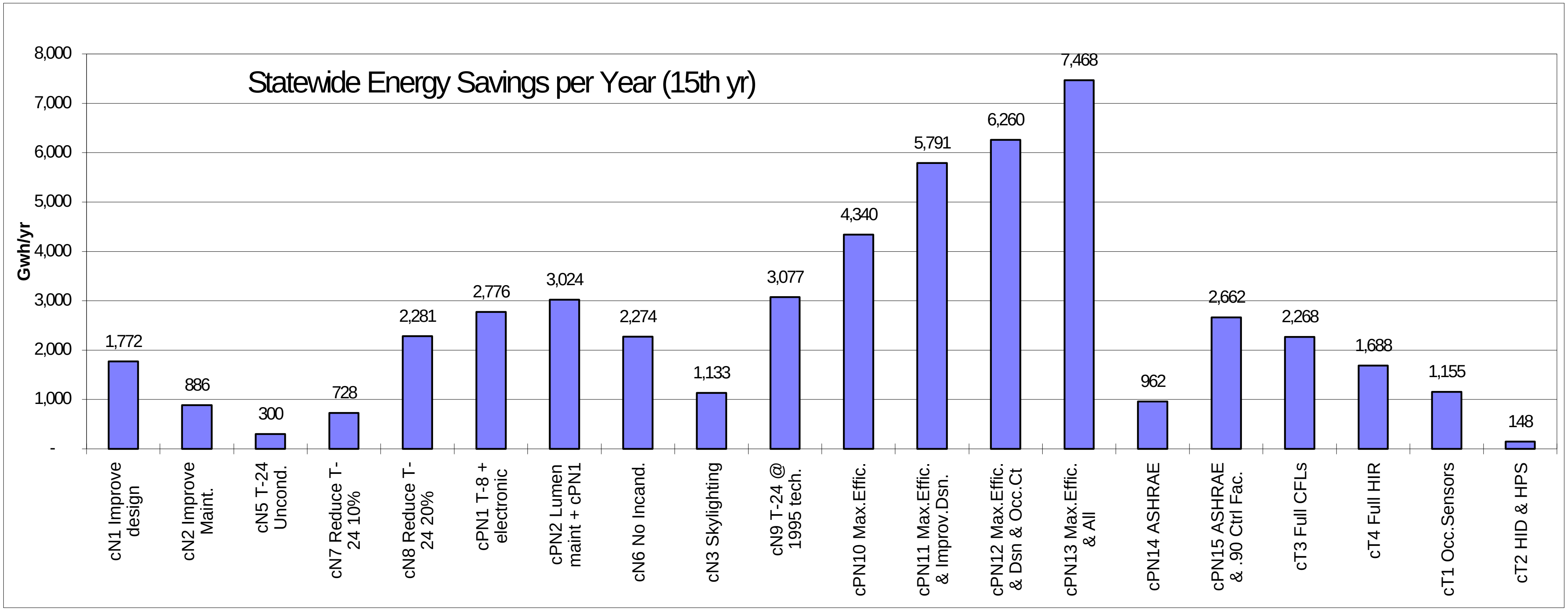



*Figure 4-10 - Statewide Energy Savings (15th year) - Commercial*

Figure 4-10 looks at the yearly energy savings from each scenario achieved in the 15$^{th}$ year (i.e. at full penetration). Energy savings from residential scenarios fall into the same range, 252 to 7,940 gigawatthours. See Figure 3-3 to compare. To gain perspective, consider that PG&E reports that one of the two nuclear units at Diablo Canyon produces about 8 billion kWh, or 8,000 gigawatt hours, per year. These energy savings have also been translated into statewide dollar savings in Figure 4-14.

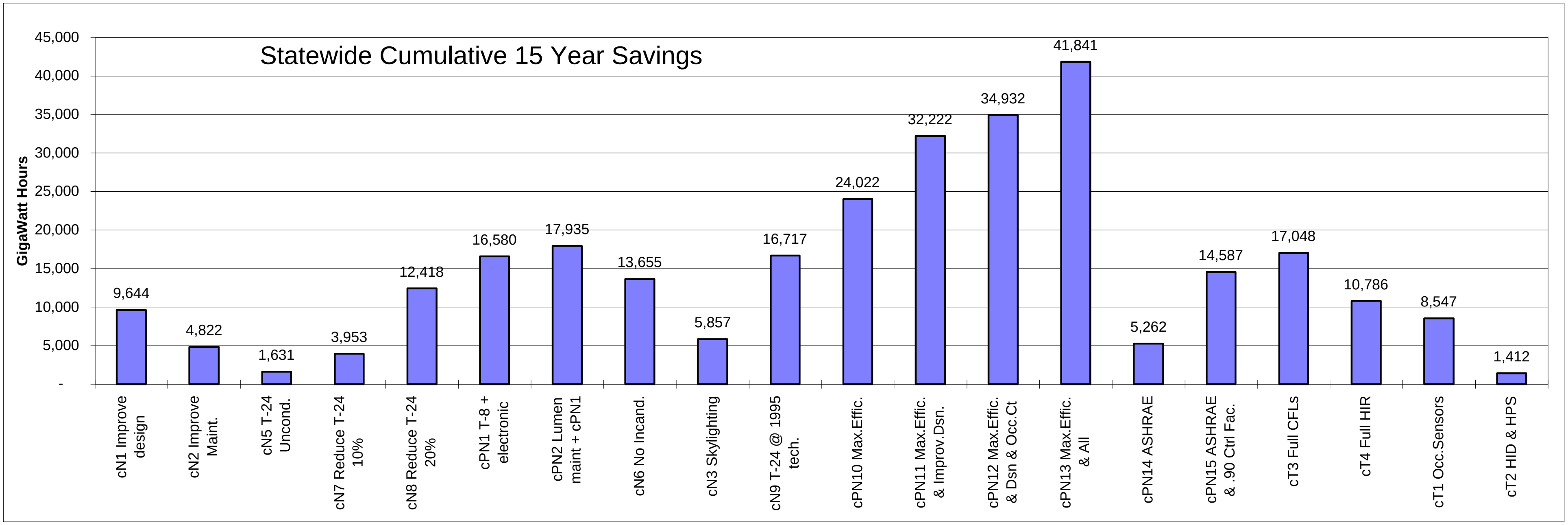



*Figure 4-11 - Statewide Cumulative 15 Years Savings - Commercial*

Figure 4-11 graphs the cumulative energy savings from each scenario over the whole 15 year study period. Energy savings increase each year as the lighting efficiency measure achieves greater penetration. The cumulative savings are effected by the assumptions about the penetration rates in the scenario. And early penetration will result in greater cumulative savings than a late penetration. The 15 year cumulative savings are especially useful when evaluating environmental impacts, such as improvements in air quality.

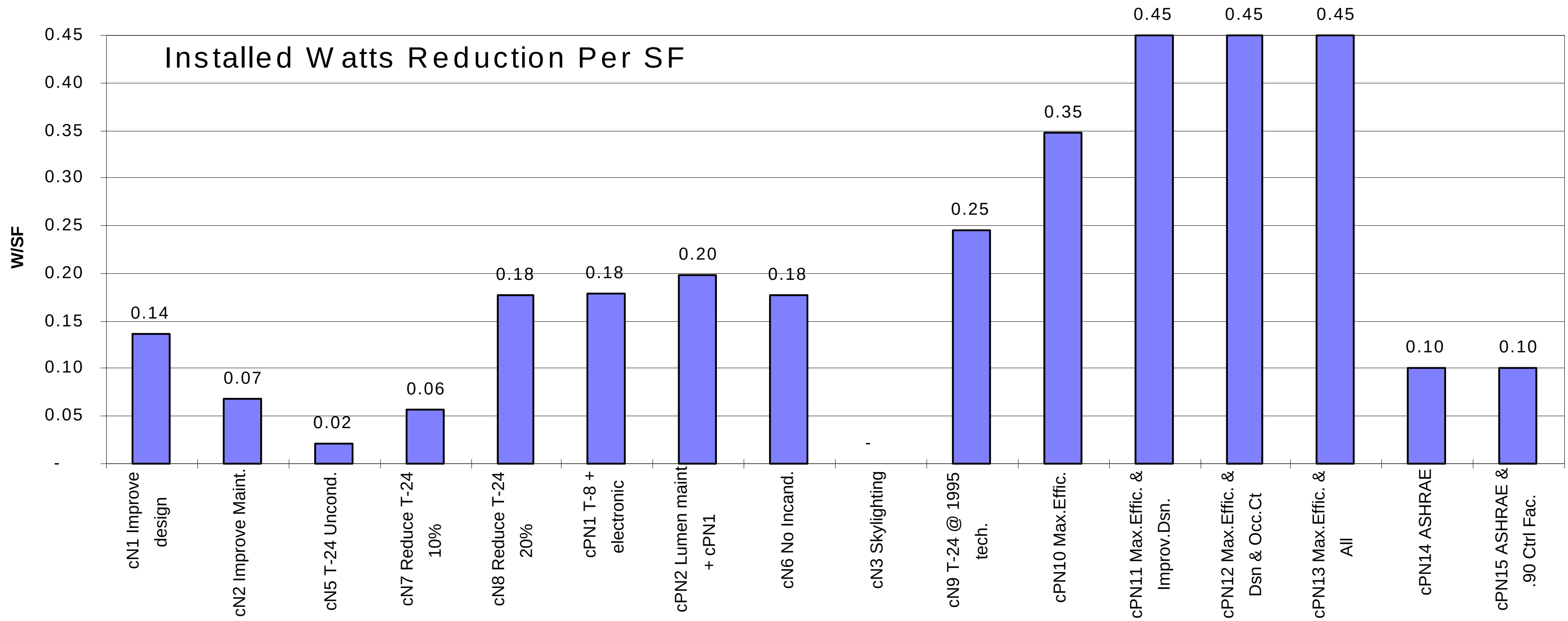



*Figure 4-12 - Installed Watts Reduction per sf - Commercial New Construction*

Figure 4-12 graphs the installed wattage reduction for new buildings constructed in the 15th year of the scenario. Values of Watts/sf, or lighting power density (LPD) for commercial buildings are often used in energy codes, or to assess the overall energy efficiency of a lighting system. The statewide average watts per square foot of commercial buildings in 1995 was found to be 1.48 watts/sf. Watts/sf by building type are graphed in Section 4.3 of Volume 1.

It should be remembered that these values are averages across all building types. Some building types are likely to be more affected by a given scenario, and thus see larger reductions, while others would be less affected.

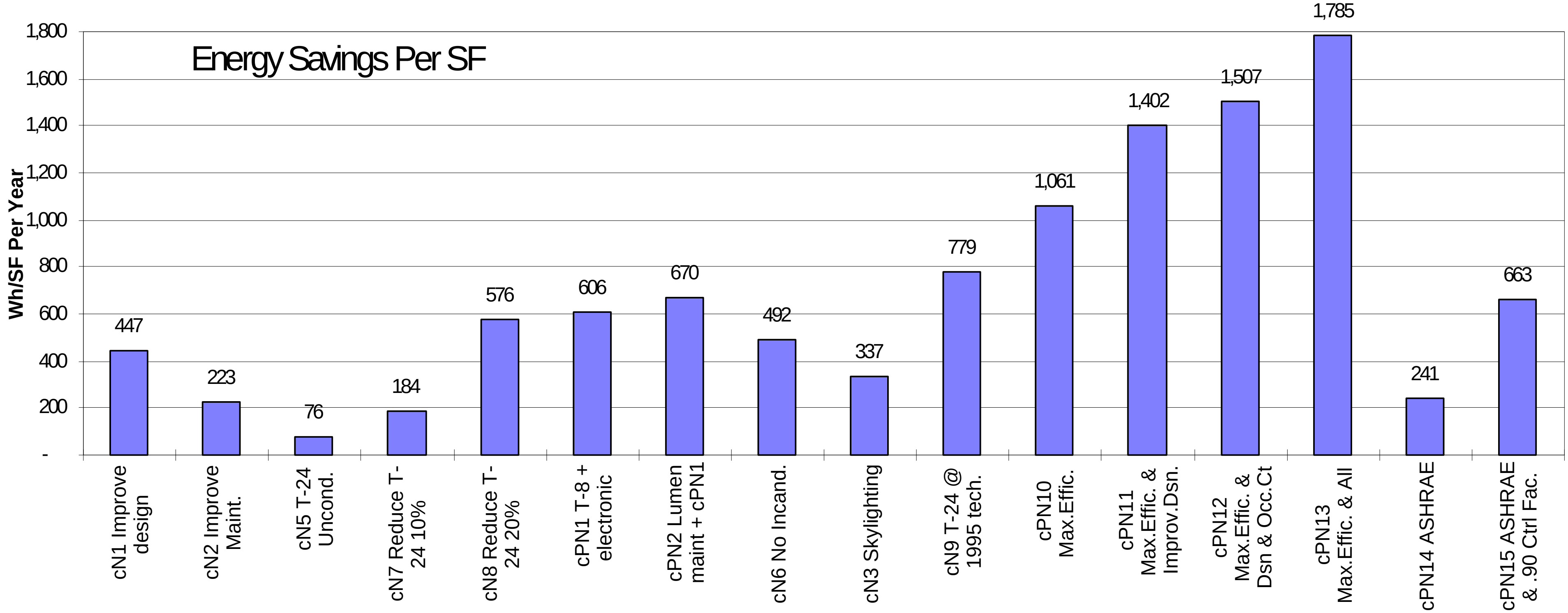



*Figure 4-13 - Energy Savings per Square Foot per Year - Commercial New Construction*

Figure 4-13 looks at the average energy savings per square foot per year for each scenario. These values are converted into dollar savings per square foot in Figure 4-15.

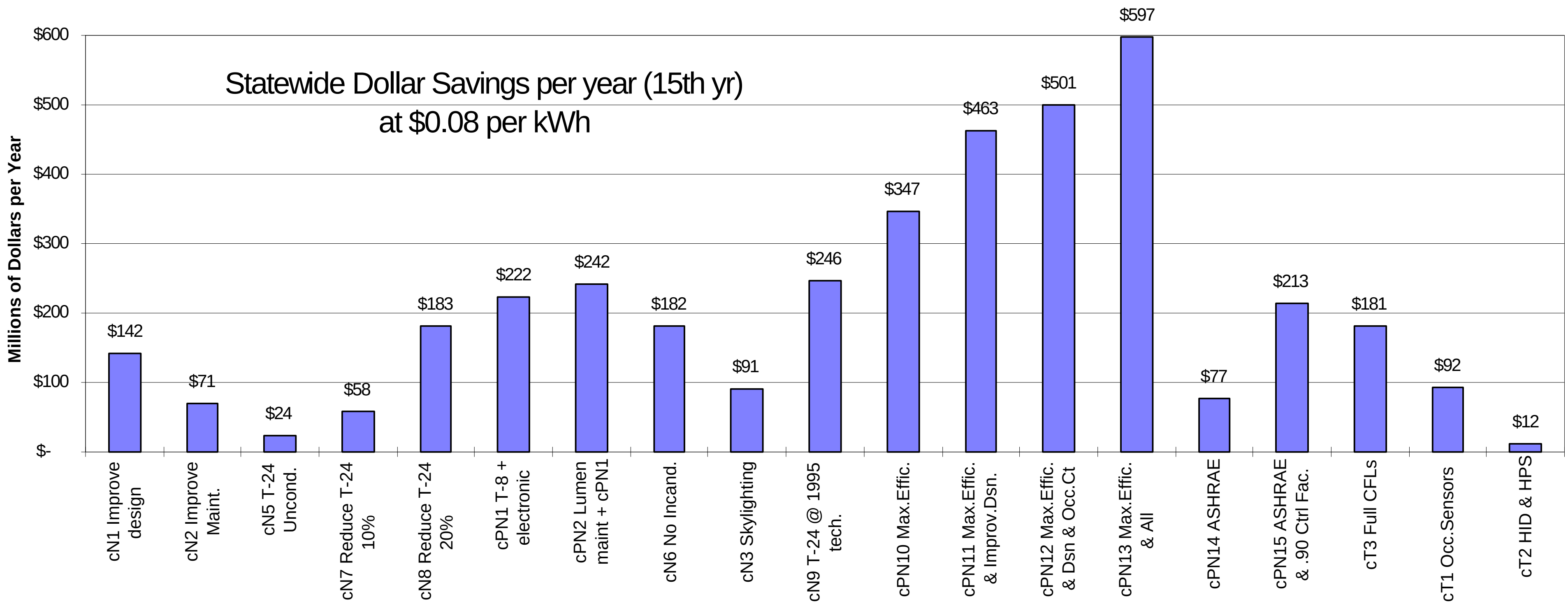



*Figure 4-14 - Statewide Dollar Savings per Year (15th Year) - Commercial*

Figure 4-14 looks at the value of statewide energy savings in the final year of the scenarios. The energy savings are simply multiplied by the national average cost of energy for commercial users in 1996, about $0.08 per kWh. The California statewide average is currently closer to $0.10/kWh, and is as high as $0.12 in many locations, however it is predicted to move towards the national average with deregulation. These values are provided to provide perspective, and do not account for inflation or the present value of money.

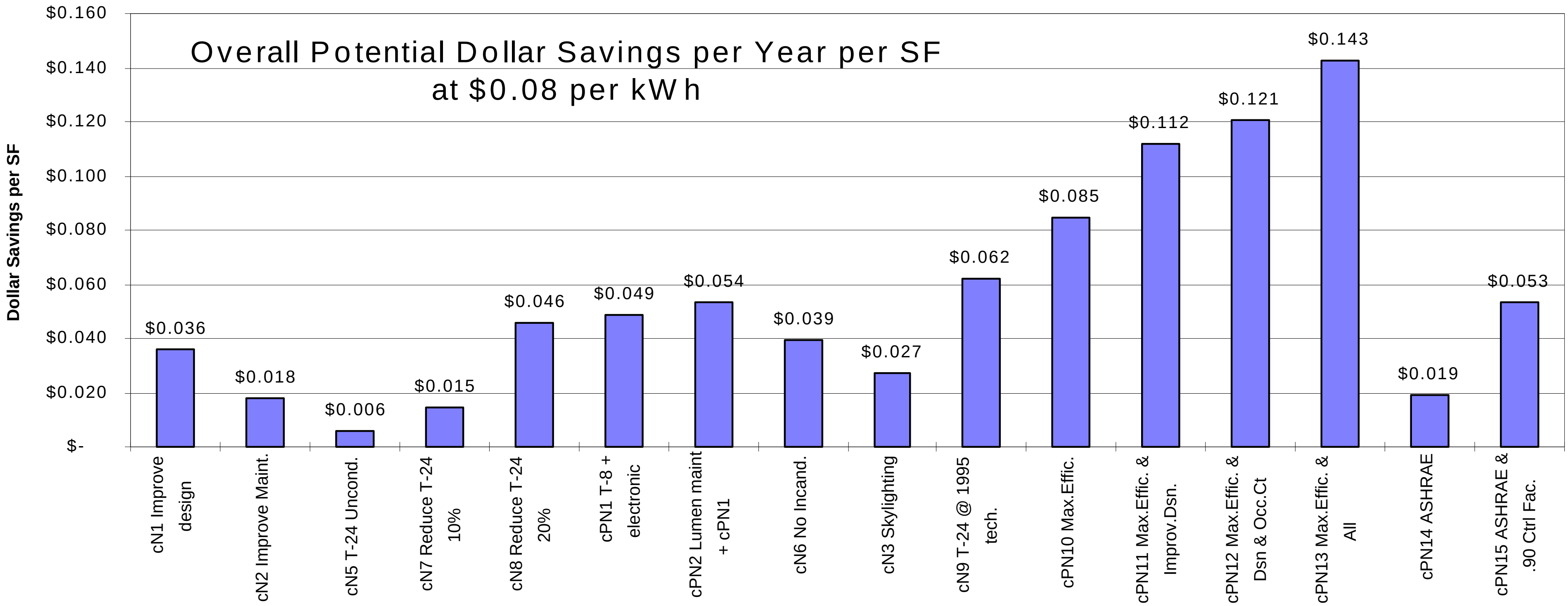



*Figure 4-15 - Overall Dollar Savings per Year per sf - Commercial New Construction*

Figure 4-15 translates the average energy savings per square foot of commercial construction in the 15th year of the scenario to dollars saved by square foot of building space. Again, it should be remembered that these are averages across all building types; some scenarios may affect a few building types more than others, and have a significantly larger or smaller effect.

For comparison, average commercial leases in California in 1995 were $12 to $24/sf per year, with an additional $2 to $3.50 possible for utilities and taxes. With average savings of $0.085/sf from scenario cPN10, a million square foot office building would save $85,000 per year, and a 20,000 sf retail store would save $1,700 per year in electricity costs. These simple values do not include any impacts from additional cooling savings or reduction in demand charges.

### 4.2.4 Combined Residential and Commercial Scenarios

Two sets of residential and commercial scenarios had very similar policy assumptions, and could logically be combined into a single scenario that would simultaneously impact both the residential and commercial sector. These were residential scenarios T8 and T9, simulating respectively penetration of halogen infrared (HIR) or CFL lamps into the residential market for incandescent lamps which are operated for three or more hours per day, and commercial scenarios cT3 and cT4, simulating respectively CFL and HIR lamps penetration into the commercial market for incandescents at varying rates dependent upon their operating characteristics (see the scenarios for more detailed description). If a CFL or HIR were price competitive and aggressively marketed, they would likely penetrate into both the residential and commercial market over the 15 year study period. Thus, we looked at their combined effects, and found them suprizingly significant. The combined scenarios were comparable to the most aggressive of the commercial scenarios, cPN10 and cPN13, which are included in the following graphs for comparison.

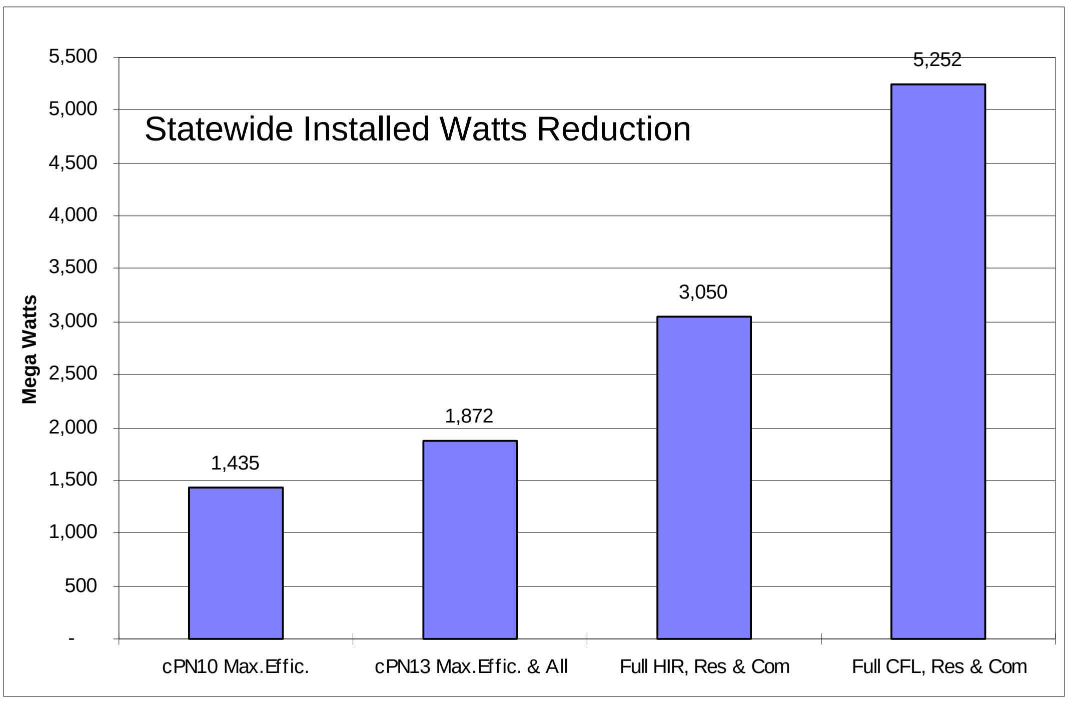



*Figure 4-16 - Combined Scenarios, Installed Watts Reduction*

The installed watts reduction for the combined scenario is dramatic, as shown in Figure 4-16, the largest of any scenarios considered, because it includes the huge installed wattage reductions available from residential scenarios with the large populations from commercial scenarios. When demand reductions are considered, shown in the following graph Figure 4-17 the impact is reduced by 1/3 or ¼, however it is still on a par with the other scenarios shown for comparison.

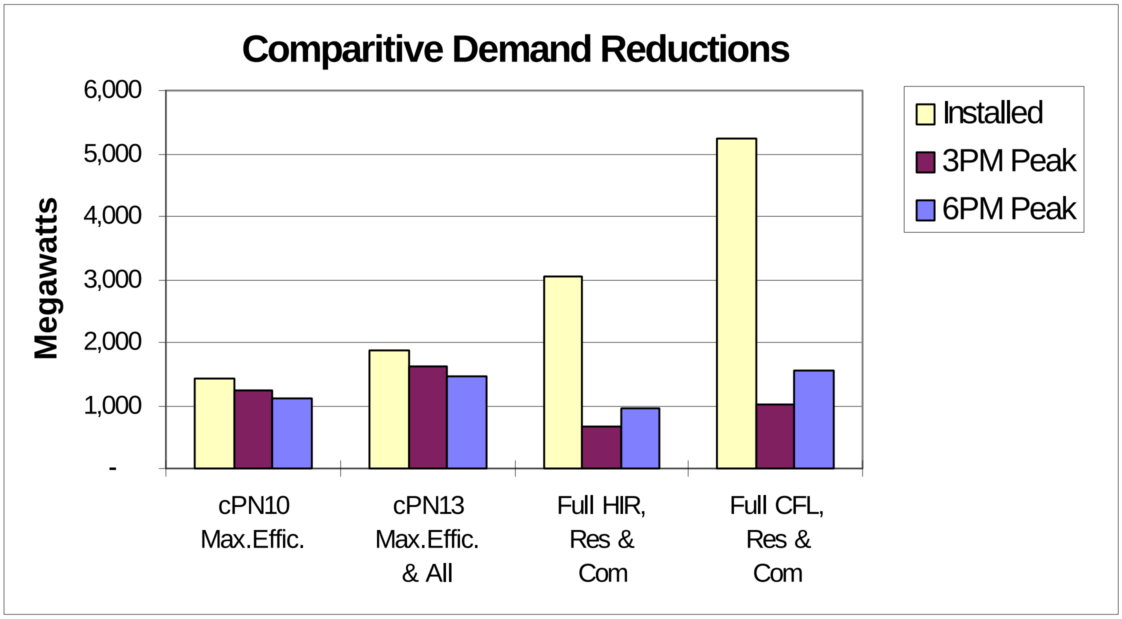



*Figure 4-17 - Combined Scenarios, Demand Reductions*

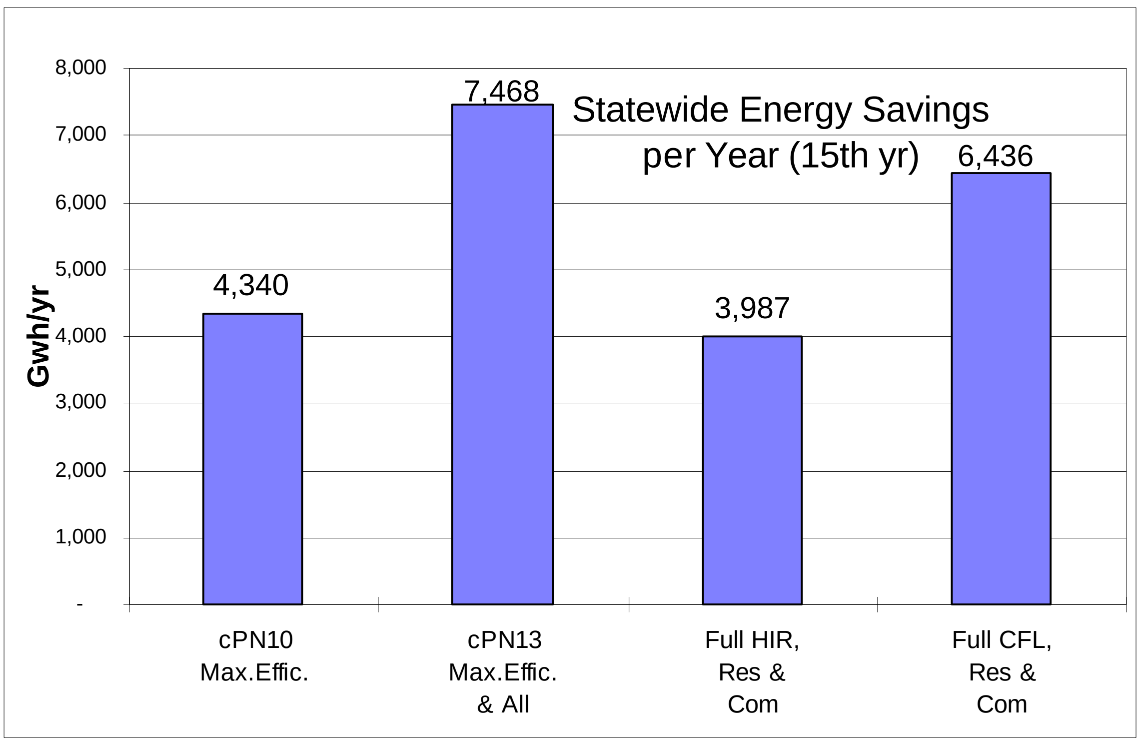



*Figure 4-18 - Combined Scenarios, Energy Savings*

In Figure 4-18 above, the HIR scenario is seen to have the same yearly energy savings as cPN10, taking all commercial lighting up to its 1995 maximum technology efficiency levels. Full penetration of CFLs is seen to have almost (86%) of the yearly energy savings possible with taking all commercial lighting up to maximum efficiency (cPN10), including skylighting, controls and advanced design techniques.

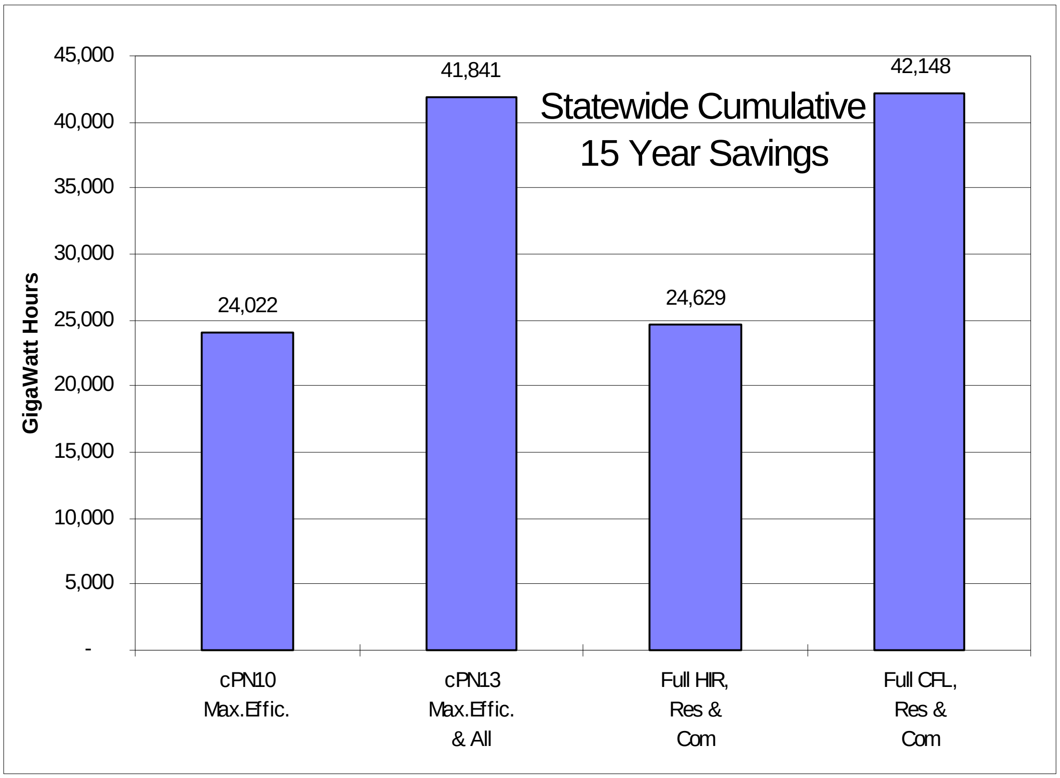



*Figure 4-19 - Combined Scenarios, Cumulative Savings*

Figure 4-19 presents the cumulative energy savings from 15 years for the four scenarios compared previously. Given the assumptions for each scenario, it is seen that the energy savings over time are very equivalent.

# 5. APPENDICES

# 5.1 Appendix A: California Lighting Model

## 5.2 Appendix B: Residential Model Inputs

## 5.3 Appendix C: Commercial Model Inputs

## 5.4 Appendix D: Residential Scenario Specifications

## 5.5 Appendix E: Commercial Scenario Specifications